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MATERNAL INFLUENCE ON BODY WEIGHT [1]

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THE weight of a litter of suckling mice has been suggested by Falconer (1947) and Bateman (1954) as a useful quantitative trait for study because of its obvious relevance to lactational and maternal traits in domestic animals. In view of the apparent difficulty experienced in improving comparable traits in livestock, the need for an intensive analysis of such traits is clearly indicated (Dickerson, 1951).

In mice the only practical method of measuring milk yield is by a function of litter weight. MacDowell *et al.* (1930) and Butler and Metrakos (1950) have shown that individual mouse weights during the suckling period are strongly influenced by the quantity of milk available. Bateman (1954) made use of a cross-nursing experiment designed to partition the variance of individual 12-day weights into components arising from prenatal influences and from postnatal influences. Bateman's study indicated that only 32% of the total variance in 12-day weight was attributable to post-natal factors; whereas the prenatal accounted for 41% of the total variance. His results suggested that the litter weight at 12 days may be a relatively insensitive measure of maternal performance.

Chapman (1946) also has made use of the cross-nursing technique in rats to study the importance of sources of variation in the weight response of the immature rat ovary to a standard dose of gonadotropin. Prenatal maternal effects on this trait were negligible; although temporary postnatal maternal effects accounted for 6% of the variance in ovary weights which had been adjusted for monthly and body weight differences.

The present report concerns a cross-nursing study paralleling Bateman's, which was carried out to investigate the maternal influence on body weight through 6 weeks of age and to test further the suitability of litter weight at 12 days as a measure of maternal performance.

Materials and Methods

The mice used in this study came from the unselected control group of a colony maintained for selection studies of body weight and maternal performance. The foundation of the colony was formed in January, 1955, by crossing two F_1 stocks (CAF_1, AKF_1) representing four different inbred lines maintained at the Roscoe B. Jackson Memorial Laboratory.

[1] Contribution from the Departments of Animal Industry and Experimental Statistics, North Carolina Agricultural Experiment Station, Raleigh, N. C. Published with the approval of the Director of Research as Paper No. 945 of the Journal Series.

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[3] The authors gratefully acknowledge the advice and technical assistance of B. R. Farthing and S. T. Farthing.

TABLE 1. AVERAGE WEIGHTS (GM.) OF 254 MALES AND 225 FEMALES IN CROSS-NURSING STUDY

Age	Males	Females
Birth	1.41	1.40
5 days	3.03	2.91
12 days	6.52	6.47
21 days	9.50	9.40
6 weeks[a]	21.87	18.90

[a] Due to death losses only 253 males and 220 females were weighed at 6 weeks.

The control population is maintained each generation as 15 male parents each mated to two female parents. One male parent and one female parent are chosen at random from each paternal half-sib family and each full-sib family, respectively. Mates are assigned to each other at random except full and half-sib matings are avoided.

During the seventh, eighth and ninth generations after the original F_1's were crossed, mice which were not used to maintain the control line were employed in the cross-nursing experiments. Single pair matings were made, avoiding the mating of full and half sibs. Groups of three unrelated litters born in the same 12-hour period and consisting of at least six mice each were established.

The individual young mice were identified, weighed and divided among the three dams in a group so that each dam received two of her own mice and two from each of the other two females in the group. Whenever possible young mice in a pair were of opposite sex. The mice were again weighed at 5, 12, and 21 days of age. At 21 days they were weaned and segregated by sex into separate cages. The final weighing was made 6 weeks after birth, which is the approximate time of sexual maturity.

The average weights of males and females at the various ages are given in table 1. Sex had little influence on the weights except at 6 weeks of age. The weights at 6 weeks were adjusted for sex differences by a multiplicative factor similar to the one described by Falconer (1953).

Analysis of variance and covariance was conducted on individual weights at various ages within the groups of three dams in the three generations. The form of analysis for a single cross-nursing group is as given in table 2.

TABLE 2. ANALYSIS OF VARIANCE FOR ONE CROSS-NURSING GROUP SHOWING THE COMPOSITION OF MEAN SQUARES

Source of variation	d.f.	Expected composition of mean square
Total	17	
Prenatal influences	2	$\sigma^2_e+2\sigma^2_{ap}+6\sigma^2_a$
Postnatal influences	2	$\sigma^2_e+2\sigma^2_{ap}+6\sigma^2_p$
Prenatal x Postnatal	4	$\sigma^2_e+2\sigma^2_{ap}$
Within pairs of full sibs	9	σ^2_e

Death losses during the experiments gave rise to unequal subclass numbers. To account for this disproportionality the components of variance were estimated by Method I as described by Henderson (1953).

Further analyses of variance were carried out using the 12-day weights of litters obtained from the control line during the fourth through the tenth generations of the colony. These analyses were directed at estimating the variance due to the direct effect of the sire on the 12-day weight of the litter, and also to assess the variance ascribable to the transmitted influence through the dam of the litter. Litters of less than five mice were not used in these analyses and those litters with only five mice were adjusted to a basis of six mice by multiplying the litter weight by 1.2.

TABLE 3. ANALYSIS OF VARIANCE FOR WEIGHT AT BIRTH (X_1), FIVE DAYS (X_2), TWELVE DAYS (X_3), TWENTY ONE DAYS (X_4), AND SIX WEEKS (X_5)

Source of variation	Degrees of freedom	X_1	X_2	X_3	X_4	X_5
		Mean squares				
Prenatal	67	0.0328	0.2958	0.6699	1.3867	5.6601
Postnatal	57	0.0104	0.9461	2.9005	6.4282	7.6038
Prenatal x Postnatal	97	0.0060	0.1128	0.2418	0.6864	2.0740
Within	227	0.0084	0.0808	0.1896	0.4458	2.2440
		Components of variance				
Prenatal (σ^2_a)		0.0056	0.0314	0.0679	0.1062	0.7217
Postnatal (σ^2_p)		0.0006	0.1554	0.4978	1.0875	1.0188
Prenatal x Postnatal (σ^2_{ap})		−.0010	0.0254	0.0529	0.7710	−.0208
Within (σ^2_e)		0.0084	0.0808	0.1896	0.4458	2.2440
		Components as percent of total [a]				
Prenatal (σ^2_a)		38	11	8	6	18
Postnatal (σ^2_p)		4	53	62	60	26
Prenatal x Postnatal (σ^2_{ap})		0	9	7	10	0
Within (σ^2_e)		58	27	23	24	56

[a] Negative estimates of these components assumed as zero.

Results and Discussion

Cross-nursing. The analysis given in table 2 indicates that the variance in the individual weight at the various ages can be partitioned into four components. The mean squares pooled within groups and generations for all the cross-nursing studies are given in table 3. The components of variance and the percentages they represent of the total variance are also given.

The prenatal component (σ^2a) includes the variance due to genetic differences in weight which exist among full sibs (Cockerham, 1954). In addition, this component includes the variance resulting from the influence of prenatal environment provided the developing fetus by the dam, through

such factors as nutrition and litter size. Many such influences are classed as genetic with regard to the dam, but they are classed as environmental from the standpoint of the young mice.

The postnatal component (σ^2p) includes the variance arising from the direct maternal (mainly nutritional) influences on the weight of the suckling mice. These prenatal influences are environmental as far as the young mice are concerned, but they would include both genetic and environmental components when classified with respect to the dam. The expectation of this component for birth weight is zero. At 5, 12, and 21 days, the postnatal component should reflect the lactational performance of the dam. At 6 weeks of age the postnatal component indicates the degree to which early suckling environment influences the variance in post-weaning weight.

The postnatal by prenatal component (σ^2ap) can be considered the result of genotype by environment interactions. Influences resulting from any synergism of the genotype of the mouse with the nutritional (milk) and cage environment provided by its foster mother would contribute to this component. Pleiotropic effects for transmitted and postnatal influences of the dam on the progeny do not contribute to this interaction. The design of the cross-nursing groups has balanced out this influence, since the mice nursed by each mother have the same average genetic value.

All effects not included in the above components contribute to the variance within pairs of full sibs born and reared alike (σ^2e). This component will include the remaining genotypic variance in weight and the random environmental influences.

In interpreting the components for birth weight a point of procedure should be emphasized. The birth weights were taken when the groups were made up, and since dams were checked every 12 hours for new litters a difference of 12 hours in initial age was possible. Consequently the prenatal component for birth weight may contain some initial postnatal influence which resulted from suckling immediately before the group was made up. The prenatal and error components include almost all the variation in birth weight. Except for sampling fluctuations the postnatal by prenatal component is expected to be zero, since postnatal influences have not been experienced at this point by the young mice.

The immediate and large influence of the postnatal environment is shown by the results for the weight at 5 and 12 days, where postnatal influences account for 53 and 62% of the total variance.

The young mice begin to consume solid food as soon as their eyes open, at around 12 days, and after this time the individual genetic factors influencing weight would be expected to become more important. Nevertheless, the variance in the weight at 21 days is still largely influenced by the postnatal maternal influence, although at 6 weeks this influence has declined by approximately 50%.

Genetic differences in the growing mice become more important as the

postnatal influence of the dam declines. The prenatal component represents 18% of the total variance in weight at 6 weeks.

The postnatal by prenatal interaction component is not large at any of the ages studied. A test for a general fostering effect was made by using mice from the complete groups to compare all mice raised by their own dam with those mice that were fostered. However, no significant fostering effect was detected.

The results of this cross nursing work do not substantiate the findings of Bateman (1954). Bateman's work showed that the prenatal environment accounted for 41% of the variation in 12-day performance after corrections had been made for birth weight and for the genotype of the individual suckling mouse. Without either of these corrections the results of the present study indicate that only 8% of the variance in 12-day weight is conditioned by the prenatal environment. Bateman suggested that 12-day litter weight may not be a sensitive measure of lactation since only 32% of the variance in his material could be attributed to postnatal factors. This study indicates that over 62% of the variance is the result of postnatal influences which presumably makes the weight of the litter at 12 days considerably more sentitive to differences in milk production of the dam than was found in Bateman's material.

Measuring Maternal Performance. Falconer (1947) discussed the use of various measures of maternal performance based on the weight of the suckling mice. The first 12 days constitute a period when the diet is entirely milk, so that the weight at the end of this period can be taken as a measure of maternal performance. Falconer also pointed out the possibility of using growth over a short period during the suckling stage, e.g., the 5th to the 12th day. Considering the growth from 5 to 12 days and weight at 12 days, Falconer found the weight at 12 days to be more sensitive in indicating postnatal differences between dams.

For measuring the maternal performance of individual dams, the desired function of 12-day weight would be one that maximized the percentage of the total variance which would be included in the postnatal component. To investigate an appropriate expression for maternal performance, an analysis of covariance was carried out with the weight at 12 days on the weights at birth and 5 days. Mean products and components of covariance for this analysis are given in table 4. The mean squares and components of variance for birth, 5 and 12 days were presented earlier in table 3.

The variance components (table 3) indicated that little of the variation in 12-day weight is due to the genotype of the suckling mouse or the suckling mouse's prenatal environment. Hence, any correction for these effects based on birth and 5-day weights will be small. For example, a measure of maternal performance expressed as the difference between birth weight and 12-day weight, computed using the components of variance and covariance from this study, would increase the percentage of variance represented by the postnatal component only 4% and would rediuce the

percentage in the prenatal component 2%. Since little increase in the percentage for the postnatal component results from correcting 12-day weight for birth weight; and, since the procedures for recording birth weights are impractical in the regular colony, a birth weight correction is not justified. Furthermore, the total weight of a litter of six mice rather than individual mouse weights is used to measure lactational performance, and the intralitter portion of the relationship between individual birth and 12-day weights would have little influence on the total weight of the litter at 12 days.

The components of covariance between 12-day weight and 5-day weight show that the major part of the covariance is associated with postnatal

TABLE 4. COVARIANCE ANALYSIS FOR BIRTH WEIGHT (X_1) AND FIVE-DAY WEIGHT (X_2) WITH TWELVE-DAY WEIGHT (X_3)

Source of variation	Degrees of freedom	$X_1 X_3$	$X_2 X_3$
	Mean products		
Prenatal	67	0.0897	0.3842
Postnatal	57	0.0212	1.4068
Prenatal x postnatal	97	0.0232	0.1482
Within	227	0.0192	0.0793
	Components of covariance		
Prenatal		0.0139	0.0390
Postnatal		—.0012	0.2353
Prenatal x postnatal		0.0027	0.0489
Within		0.0192	0.0793

differences. A correction of 12-day weight by a function of 5-day weights, such as the regression of 12-day weight on 5-day weight, will necessarily remove some of the postnatal differences between nursing dams. Furthermore, the regression coefficient which maximized the postnatal variance as a percentage of the total variance increased this percentage only 2%. Hence, the results suggest that the actual weight of the litter at 12 days is a satisfactory measure of direct postnatal influence.

While substantiation of the importance of the influence of the nursing dam on the 12-day weight of a litter standardized to six mice is essential to its acceptance as a measure of maternal performance, further analysis of the genetic variability is needed to assess its expected response to selection. The genetical interpretation of the components of variance from the cross-nursing experiment has been pointe d out. However, the 12-day weight of a standardized litter of six mice rather than the weight of individual mice is being used as the measure of performance in the selection studies for high and low 12-day weight.

The within generation variance for the 12-day weight of litters of six mice was computed as 25.08 using 177 litters of control line females from the fourth through the tenth generation (table 5). Prenatal and postnatal

TABLE 5. ANALYSIS OF THE IMPORTANCE OF THE DIRECT INFLUENCE OF THE SIRE ON THE 12-DAY WEIGHT OF LITTERS OF SIX MICE

Source of variation	d.f.	M.S.	Expected composition of M.S.	Components
Total	176	31.62		
Generations	6	218.19		
Sires in generation	92	26.20	$\sigma^2+1.780\sigma^2_s$	1.43
Within sires	78	23.65	σ^2	23.65

influences detected in the cross-nursing study would be similar for litter mates. As a consequence, variance for prenatal and postnatal differences for litters of size n (σ^2l) can be derived from the corresponding components from the cross-nursing on an individual mouse basis (σ^2_i) according to the relationship: $\sigma^2 1 = n\sigma^2 i + n(n-1)\sigma^2 i$. Accordingly the prenatal component for litters of six mice would be 2.44, and this represents 9.7% of the variance in 12-day litter weight. This component would be expected to include one-half of the genic variance, one-quarter of the dominance variance, variance resulting from intra-uterine environmental effects, and a portion of possible epistatic variance. The genic component contributing to the similarility between full sibs was estimated from the direct influence of the service sire on the 12-day weight of the litter as given in table 5. Since the sire component (1.43) is an estimate of one-quarter of the genic variance, one-half of the genic variance representing the minimal content of the variance among sets of full sibs would be 2.86. This rather close agreement with the value of 2.44 derived from the cross-nursing study suggests that the influence of the genotype of the mouse on its 12-day weight can be adequately described by additive effects.

Using the postnatal component for individual mice from the cross-nursing study, a value of 17.92 was obtained for the postnatal contribution to the variance in the 12-day weight of litters of six mice. This represents 71.5% of the total variance on a litter basis as compared to 61.6% on an individual mouse basis. Both the prenatal and the postnatal influences contribute to observed differences among litters. The variance associated with these influences represents slightly more than 81% of the total variance in 12-day litter weight.

TABLE 6. ANALYSIS OF THE IMPORTANCE OF SIRE ON THE 12-DAY WEIGHT OF HIS DAUGHTER'S LITTERS

Source of variation	d.f.	M.S.	Expected composition of M.S.	Components
Total	176	31.62		
Generations	6	218.19		
Sires in generations	89	26.73	$\sigma^2+1.822\sigma^2_s$	1.95
Within sires	81	23.17	σ^2	23.17

An estimate of the heritability of 12-day weight can be obtained from the sire component acting through the dams of the litters. This analysis for the same litters as were included in table 5 is presented in table 6. Four times the sire component gives an estimate of 7.80 for the genic variance, representing a value of $0.31 \pm .46$ for heritability. Both the genotype for individual growth rate (g_i) and the genotype for maternal performance of the dam (g_j) must be considered in interpreting heritability estimates for 12-day weight. If epistasis is negligible, four times the sire component from table 6 represents $\sigma g^2 i/4 + \sigma g^2 j + \sigma g_i g_j$.

Dickerson and Grimes (1947) and Bradford *et al.* (1958) in swine, and Koch and Clark (1955) for beef cattle suggest that the covariance between g_i and g_j is negative. The correlation between the prenatal and postnatal influences was estimated directly from the data on cross-nursing by relating the weights of the litters dropped to the weights of those weaned by the same dam. For 12-day weight this correlation was —0.28 for 12 cross-nursing groups that had all cells filled. Data now being collected in the colony will afford an opportunity to examine this relationship more fully. Such information should be especially pertinent to an examination of the relationship between the genotype for growth and the genotype for maternal performance in connection with livestock breeding problems. With some variation, procedures used in these studies may find useful application in work with swine.

Summary

A cross-nursing experiment in mice was employed to study the relative contributions of prenatal and postnatal factors to body weight at 5, 12 and 21 days and 6 weeks. Postnatal maternal influence was found to be the most important single factor in determining weight through weaning. The weight at 12 days was largely controlled by postnatal factors which suggested its use as a measure of lactation performance in the dam. Postnatal maternal influences accounted for 71.5% of the variance in the 12-day weight of litters of six mice. The prenatal influences accounted for an additional 9.7% of the variance in 12-day litter weight.

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THE COMPARATIVE ENERGY REQUIREMENTS OF SHEEP AND CATTLE FOR MAINTENANCE AND GAIN [1]

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AN adequate energy supply is of primary consideration in the feeding of any animal. The question arises whether the assessment of energy requirements for maintenance and production with one species can be properly applied to another similar species. It is usually accepted that what applies to cattle applies also to sheep, at least as far as the utilization of a feed is concerned. Calculated comparisons between sheep and cattle are not infrequent, and various aspects of comparative nutrition can be found in the literature (Guilbert and Loosli, 1951; Mitchell, 1945; Brody, 1945).

A search of the literature, however, reveals no instance in which the energy requirements for maintenance and gain in sheep and cattle have been directly compared with each species receiving its energy from an identical source and under similar environmental conditions. This is not surprising because to make a valid comparison between these two species a measure of energy retention is necessary. Weight gain alone is not a suitable criterion of response to different feeding regimes, since the chemical composition of the gained tissue may not be identical in all animals.

This experiment had for its specific purpose the direct comparison of the energy requirements of sheep and cattle for maintenance and gain. It was designed to enable the calculation of these requirements on the basis of total digestible nutrients (TDN), digestible energy (DE), metabolizable energy (ME), and net energy (NE). The response to the different feeding regimes was measured by body-weight gain and by energy gain.

Experimental

The chemical composition of a beef animal can be estimated from the specific gravity of the dressed carcass according to a procedure described by Kraybill *et al.* (1951–52) and from information given by Reid *et al.* (1955). The use of this procedure would eliminate the expensive, time-consuming task of sampling and chemical analysis necessary in the usual comparative slaughter experiment. The method is as follows: The specific gravity of the dressed beef carcass is determined by underwater weighing. The percentage of fat in the whole animal can then be estimated by a

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mathematical expression given by Kraybill *et al.* (1951–52). From this fat percentage and the equations and the procedure developed by Reid *et al.* (1955), the chemical composition of the bovine can be estimated. Representative animals slaughtered at the beginning of the trial would serve to establish the initial body composition of the experimental group. By determining the body composition of all animals at the end of the trial, the energy retention can be estimated by difference.

The Estimation of Body Composition of Sheep. The data on 59 sheep were found suitable for establishing the relationships among the major chemical constituents of the ovine body which are necessary for the indirect resolution of body composition in this species. This information was found in three reports by Mitchell *et al.* (1926, 1928, 1928a) and in the work of Lawes and Gilbert (1859). The body-composition data were all calculated to the wool-free empty-body weight basis. The following relationships were established:

1. The correlation coefficient between percent body water and percent body fat was −0.989; the standard error of estimate was ± 1.2.

Equations:

$Y=90.102-1.1656X$	Y=percent fat in the wool-free empty body
$X=76.892-0.8384Y$	X=percent water in the wool-free empty body

2. The correlation coefficient between the percent protein of the whole animal and the percent fat-free dry matter was 0.970; the standard error of estimate was ± 0.31.

Equation:

$Y=0.6707X+2.704$	Y=percent protein of the wool-free empty body X=percent fat-free dry matter of the wool-free empty body

This equation may not be absolutely essential, since the use of the average percent protein in the fat-free dry matter (80.7) gave a standard error of estimate of ±0.40 for the prediction of percent protein from the percent fat-free dry matter. This standard error of estimate is only slightly greater than that of the equation.

3. The mean percentages of the major chemical components and their standard deviations are: water, 74.99 ± 1.46; protein, 20.19 ± 1.31; ash, 4.81 ± 0.66. These values are on a fat-free, wool-free, empty-body weight basis.

4. The correlation coefficient between percent carcass fat and percent fat of the wool-free empty body was 0.989; the standard error of estimate was ± 1.18.

Equation:

$Y=0.8817X-1.520$	Y=percent fat of the wool-free empty body X=percent carcass fat

These relationships permit the resolution of body composition in sheep if either the fat content or the water content is known. The distribution of the data did not permit a study of the influence of age upon these relationships as Reid *et al.* (1955) has done in the bovine.

The validity of using body specific gravity as an index of the amount of fat present in an animal body has been established (Rathbun and Pace, 1945; Kraybill *et al.*, 1951–52; Brown *et al.*, 1951; Keys and Brozek, 1953). Twenty sheep carcasses were used to determine the relationship between percent carcass fat and carcass specific gravity. The carcasses were chosen to represent a fairly large range in degree of finish. The specific gravity of the cooled, dressed carcass was determined by weighing under water. The carcasses were then frozen and stored until sampled for chemical analysis. All weight loss between the specific gravity determination and sampling was considered to be moisture.

TABLE 1. THE CHEMICAL COMPOSITION OF THE DRESSED SHEEP CARCASS

Slaughter grade	Specific gravity	Water	Fat	Non-fat organic matter	Ash	Nitrogen[a]
		%	%	%	%	%
Choice	1.0356	44.7	37.5	13.3	4.5	15.70
Choice	1.0434	46.7	34.9	14.0	4.4	16.10
Choice	1.0443	52.1	27.5	15.6	4.8	15.98
Good	1.0398	51.6	28.6	14.6	5.2	16.16
Good	1.0536	51.8	27.9	14.9	5.4	15.75
Good	1.0578	53.5	26.3	15.0	5.2	16.06
Good	1.0568	53.9	25.3	15.5	5.3	16.18
Good	1.0474	56.5	22.4	16.3	4.8	16.15
Good	1.0661	58.2	21.8	15.6	4.4	16.27
Good	1.0499	55.3	21.5	17.1	6.1	16.03
Good	1.0463	56.1	21.4	15.6	6.9	16.00
Good	1.0639	57.3	20.7	16.6	5.4	16.11
Good	1.0617	58.1	20.4	16.1	5.4	16.07
Good	1.0564	57.8	20.0	17.2	5.0	16.32
Good	1.0629	56.7	18.6	18.2	6.5	15.52
Utility	1.0480	53.6	26.1	15.2	5.1	16.17
Utility	1.0559	57.9	19.6	16.6	5.9	15.75
Utility	1.0747	59.1	18.1	17.1	5.7	16.17
Cull	1.0733	60.1	17.5	16.7	5.7	16.12
Cull	1.0738	63.9	14.3	15.5	6.3	15.93
Mean	1.0556	55.2	23.5	15.8	5.4	16.03

[a] Percent nitrogen of fat-free, ash-free dry matter.

Each whole carcass (bone included) was ground in a one-horsepower Hobart meat grinder through a medium plate. The ground carcass was mixed by hand and the entire amount again put through the grinder. After another mixing, about one-fourth of the carcass was again put through the

Hobart grinder and mixed, and a sample was taken for analysis. Duplicate analyses were made on each carcass sample for ether extract, moisture, nitrogen, and ash. The results of these analyses are presented in table 1.

The correlation coefficient between the specific gravity of the dressed carcass and the percent carcass fat was —0.90; the standard error of estimate was ±2.6.

Equation:

$$Y=556.6-505.0X$$

X=Carcass specific gravity
Y=Percent carcass fat

The standard error of estimate for this equation was larger than anticipated. However, by assuming a carcass of 100 percent fat and one of zero percent fat, the calculated specific gravity of pure fat is 0.904 and of the non-fat is 1.102. These values agree very closely with the specific gravity of sheep fat reported by Fidanza *et al.* (1953–54) of 0.9003 and 0.9212 for subcutaneous and internal fat, respectively, and with the value of 1.10 as the commonly accepted specific gravity of the lean body (Keys and Brozek, 1953).

It is necessary to add to the energy retained in the body of the sheep that retained in the wool. All the sheep were shorn just before the feeding period. In addition, on the first day of the feeding trial an area on the right side of each sheep was clipped free of wool with a small animal clipper. A sample of wool was taken from a measured portion of this clipped area at the end of the trial. From the known area sampled and the weight of the wool produced on that area, it was possible to estimate the total fleece yield. An equation by Brody (1945) was used to calculate the surface area of the sheep. The energy content of the wool was determined by combusting a portion of each sample in a bomb calorimeter. This procedure was suggested by Wilson (1956).

The Feeding Trial. Thirty-nine grade Angus steers and 64 western whiteface wethers of predominantly Rambouillet and Corriedale breeding were the experimental animals. The experimental design was identical for both species. The steers, rather uniform in appearance and estimated slaughter grade, were considered one slaughter group. Eight animals were selected from this group for immediate slaughter. The lambs were divided into four uniform-appearing slaughter groups from which 16 lambs were selected for immediate slaughter. Each lamb thus selected represented the group with which it was placed on the basis of its estimated slaughter grade. All remaining steers and wethers were randomly (within slaughter groups) assigned one of four levels of feeding calculated to produce gains of zero, 0.1, 0.2, or 0.3 lb. per day for the sheep and gains of zero, 0.5, 1.0, 2.0 per day for the steers.

All animals were fed individually. The sheep were on feed for 91 days,

TABLE 2. SUMMARY OF THE DIGESTION TRIAL (DRY-MATTER BASIS)

Items	Metabolizable energy (kcal./kg.)	Digestible energy (kcal./kg.)	TDN (%)
Pelleted hay	2048	2536	54.7
Concentrate	2970	3458	72.0

the steers for 90 days. The pelleted roughage (54% alfalfa and 46% Sudan hay) was fed to each animal in an amount calculated to provide the maintenance energy requirement. The concentrate, a mixture of 60% ground barley and 40% cottonseed meal, was added to the maintenance allowance of pelleted hay in an amount estimated to produce the desired rate of gain. This concentrate mixture was used in order to obtain its energy value for fattening, with the future possibility of measuring partial replacement equivalents in terms of this mixture, as suggested by Kleiber (1945).

Digestion Trial. A 4 x 4 Latin square digestion trial with sheep was run concurrently with the main feeding experiment. Three levels of concentrate were added to a maintenance ration of pelleted hay to provide 15, 30, and 45% of the total air-dry feed. Feces were collected daily, dried in a forced air oven at 70°C for 24 hours, and the entire seven-day collection mixed, ground and quartered into the laboratory sample. Energy determinations were made in an Emerson fuel calorimeter. A known amount of urine was concentrated on a weighed quantity of cellulose power to determine its energy content. Methane production was computed from dry-matter intake

TABLE 3. SUMMARY OF THE ENERGY CONSUMPTION AND WEIGHT GAINS OF THE SHEEP AND CATTLE

Level of feeding[a]	Mean daily energy intake			Mean body weight (lb.)	Mean daily gain (lb.)
	TDN (lb.)	DE (kcal.)	ME (kcal.)		
Sheep					
M	0.91	1924	1554	67.8	0.08
0.1	1.21	2565	2096	72.8	0.17
0.2	1.43	3050	2511	77.6	0.26
0.3	1.65	3527	2918	79.7	0.33
Cattle					
M	4.99	10501	8493	784	0.09
0.5	6.60	14003	11494	814	0.77
1.0	8.31	17747	14712	832	1.20
2.0	11.52	24723	20695	869	1.89

[a] M=Maintenance; other levels are the expected daily gain.

TABLE 4. SUMMARY OF BODY COMPOSITION AND ENERGY RETENTION OF SHEEP

Sheep	Weight at slaughter[a] (kg.)	Fat (%)	Protein (%)	Wool growth (kg.)	Energy content (megacalories)					Energy gain	
					Fat[b]	Protein[c]	Wool	Total	Initial[d]	Total (mcal.)	Daily (kcal.)
Check	28.9	17.1	16.4	....	46.2	26.4	...	72.6	....	....	...
Maintenance	31.9	18.7	16.2	0.68	55.8	28.8	3.9	88.8	74.4	14.1	155
0.1 gain	35.7	19.5	16.1	0.80	65.6	32.0	4.6	102.2	75.1	27.1	297
0.2 gain	39.8	20.5	16.0	0.80	76.3	35.7	4.6	116.6	76.0	40.6	445
0.3 gain	42.1	20.8	15.9	0.91	81.9	37.3	5.3	124.5	74.8	49.7	547

[a] Corrected for wool growth.
[b] Caloric value of fat=9354 kcal./kg. (Garrett, 1958).
[c] Caloric value of protein (fat-free, organic matter)=5570 (Garrett, 1958).
[d] Assuming same body composition as check sheep in the same slaughter group.

by a formula presented by Swift and French (1945). Total digestible nutrients were calculated from digestible energy and digestible organic matter by the methods suggested by Lofgreen (1951, 1953). Ether extract and organic matter were determined by the standard methods of the A.O.A.C. (1956). The results (table 2) for the concentrate fed at various levels were essentially the same and the mean is presented.

Results

A summary of the energy consumed and weight changes during the feeding period is presented in table 3. The data obtained from the comparative slaughter procedure are summarized in tables 4 and 5.

TABLE 5. SUMMARY OF BODY COMPOSITION AND ENERGY RETENTION OF STEERS

Steers	Slaughter weight (kg.)	Fat (%)	Protein (%)	Energy content (megacalories)				Energy gain	
				Fat[a]	Protein[b]	Total	Initial[c]	Total (mcal.)	Daily (kcal.)
Check	353.4	16.34	18.42	543.5	369.3	912.8	.....	.....	....
Maintenance	357.8	14.79	18.52	492.1	376.7	868.8	913.6	—44.8	—497
0.5 Gain	384.9	16.47	18.36	592.3	401.8	994.1	913.4	80.7	897
1.0 Gain	402.1	18.02	18.24	675.0	417.2	1092.2	911.8	180.4	2005
2.0 Gain	432.5	19.30	18.12	780.3	445.8	1226.1	905.7	320.4	3560

[a] Caloric value of fat, 9367 kcal./kg. (Blaxter and Rook, 1953).
[b] Caloric value of protein, 5686 kcal./kg. (Garrett, 1958).
[c] Assuming same body composition as check steers.

The initial energy content of the experimental animals was determined from the average chemical composition of the representative animals slaughtered at the beginning of the experiment. Therefore, average values were used in the calculations involving energy retention.

It is advantageous to describe the relationship between energy intake and energy retention by a convenient mathematical expression. This expression should be in a form which separates the maintenance energy requirement from the total energy requirement for any specific rate of production. Preliminary calculations indicated that the data could be fitted with a linear or exponential expression with almost equal reliability. The linear equation adopted was of the same type used by Winchester and Hendricks (1953). The equation has the form:

$$f = aw^b(1 + kg_e)$$

in which f represents the mean daily energy intake, w is the mean body weight for the feeding period, and g_e is the mean daily gain of energy. The constants a and k were calculated from the data. The constant b was assumed to be 0.75.

The exponential equation fitted to the data had the form:

$$f=aw^{b}k^{ge}$$

Equations were calculated describing the relationship between energy intake per unit $w^{3/4}$ and body-weight gain for comparison with those relationships established between energy intake per unit $w^{3/4}$ and energy retention. For further comparison the relationships between energy intake per unit $w^{3/4}$ and energy gain per unit $w^{3/4}$ were also calculated from the data for each species.

Figures 1 and 2 are scatter diagrams depicting some of the relationships between energy intake and weight gain or energy gain.

Table 6 gives the linear and exponential expressions which describe the relationships between energy intake and energy retention. Table 7 presents the equations relating energy intake to body weight gain. The coefficient of determination (percent of the total variation due to the linear relationship existing between energy intake and energy gain or weight gain) is given for each equation.

The Calculation of Net Energy Requirements. The data obtained in this investigation suitable for calculating net energy requirements are summarized in table 8. This information is essentially of the same nature as that obtained from direct or indirect calorimetry. The procedure used here esti-

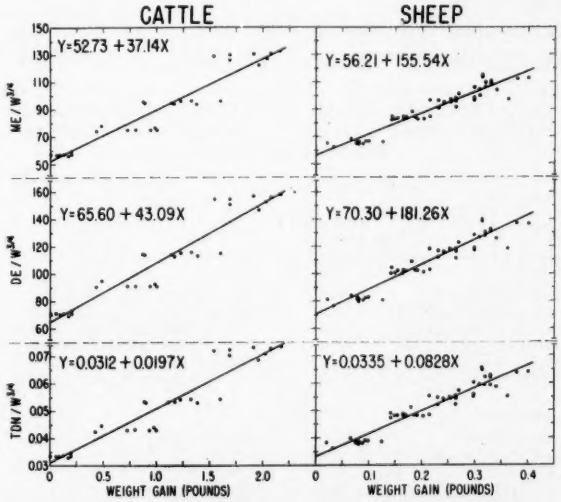

Figure 1. The linear relationship between energy intake and body weight gain in sheep and cattle.

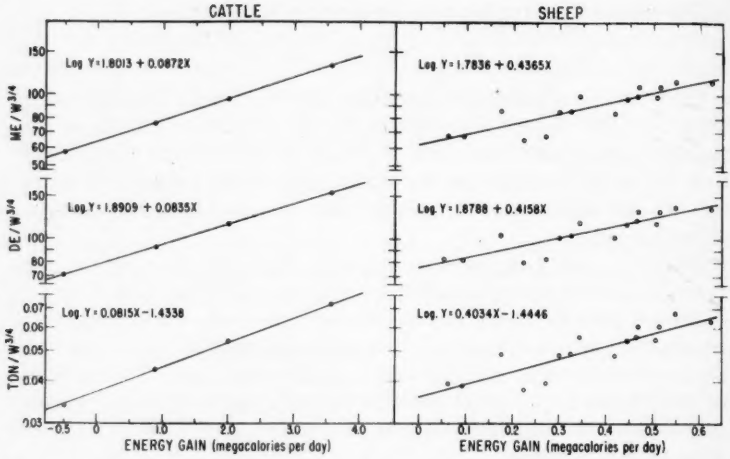

Figure 2. The exponential relationship between energy intake and energy gain in sheep and cattle.

mates energy retention directly, and heat production is calculated by difference (metabolizable energy minus energy gain). The opposite situation exists in calorimetry.

Several procedures are used in calculating net energy values. These have been recently discussed by Swift (1957) and also by Blaxter

TABLE 6. EQUATIONS DESCRIBING THE RELATIONSHIP BETWEEN DAILY ENERGY INTAKE AND DAILY ENERGY RETENTION IN SHEEP AND CATTLE

Sheep	Coefficient of determination	Cattle	Coefficient of determination
Linear equations [a]			
$ME=57.8\ w^{\frac{3}{4}}\ (1+1.50\ G_e)$	79.2	$ME=62.7\ w^{\frac{3}{4}}\ (1+0.284\ G_e)$	98.4
$ME=57.0\ w^{\frac{3}{4}}\ (1+40.8\ G_e/w^{\frac{3}{4}})$	73.2	$ME=62.8\ w^{\frac{3}{4}}\ (1+44.7\ G_e/w^{\frac{3}{4}})$	97.7
$DE=72.2\ w^{\frac{3}{4}}\ (1+1.40\ G_e)$	79.0	$DE=77.2\ w^{\frac{3}{4}}\ (1+0.268\ G_e)$	98.4
$DE=71.3\ w^{\frac{3}{4}}\ (1+37.9\ G_e/w^{\frac{3}{4}})$	73.0	$DE=77.2\ w^{\frac{3}{4}}\ (1+42.2\ G_e/w^{\frac{3}{4}})$	97.7
$TDN=0.0344\ w^{\frac{3}{4}}\ (1+1.34\ G_e)$	79.0	$TDN=0.0365\ w^{\frac{3}{4}}\ (1+0.281\ G_e)$	98.3
$TDN=0.0340\ w^{\frac{3}{4}}\ (1+36.3\ G_e/w^{\frac{3}{4}})$	73.0	$TDN=0.0365\ w^{\frac{3}{4}}\ (1+40.9\ G_e/w^{\frac{3}{4}})$	97.6
Exponential equations [a]			
$ME=60.8\ w^{\frac{3}{4}}\ (2.73)^{G_e}$	78.0	$ME=63.1\ w^{\frac{3}{4}}\ (1.22)^{G_e}$	99.9
$ME=60.4\ w^{\frac{3}{4}}\ (1.03)^{g_e/w^{\frac{3}{4}}}$	71.7	$ME=63.2\ w^{\frac{3}{4}}\ (1.03)^{g_e/w^{\frac{3}{4}}}$	99.9
$DE=75.8\ w^{\frac{3}{4}}\ (2.61)^{G_e}$	77.8	$DE=77.8\ w^{\frac{3}{4}}\ (1.21)^{G_e}$	99.9
$DE=75.1\ w^{\frac{3}{4}}\ (1.03)^{g_e/w^{\frac{3}{4}}}$	71.5	$DE=77.8\ w^{\frac{3}{4}}\ (1.03)^{g_e/w^{\frac{3}{4}}}$	99.9
$TDN=0.0359\ w^{\frac{3}{4}}\ (2.54)^{G_e}$	77.8	$TDN=0.0368\ w^{\frac{3}{4}}\ (1.21)^{G_e}$	99.9
$TDN=0.0357\ w^{\frac{3}{4}}\ (1.03)^{g_e/w^{\frac{3}{4}}}$	71.6	$TDN=0.0368\ w^{\frac{3}{4}}\ (1.03)^{g_e/w^{\frac{3}{4}}}$	99.8

[a] ME, DE and g_e are in kilocalories; G_e in megacalories; TDN and w are in pounds.

TABLE 7. EQUATIONS DESCRIBING THE RELATIONSHIP BETWEEN DAILY ENERGY INTAKE AND DAILY BODY WEIGHT GAIN IN SHEEP AND CATTLE

Sheep	Coefficient of determination	Cattle	Coefficient of determination
Linear equations [a]			
$ME = 56.2\ w^{3/4}\ (1+2.77g)$	90.9	$ME = 52.7\ w^{3/4}\ (1+0.70g)$	90.2
$DE = 70.3\ w^{3/4}\ (1+2.58g)$	90.7	$DE = 65.6\ w^{3/4}\ (1+0.657g)$	90.2
$TDN = 0.0335\ w^{3/4}\ (1+2.47g)$	90.7	$TDN = 0.0312\ w^{3/4}\ (1+0.633g)$	90.2
Exponential equatons [a]			
$ME = 59.7\ w^{3/4}\ (6.12)^{g}$	90.5	$ME = 56.4\ w^{3/4}\ (1.53)^{g}$	92.0
$DE = 74.2\ w^{3/4}\ (5.62)^{g}$	90.3	$DE = 69.7\ w^{3/4}\ (1.50)^{g}$	91.9
$TDN = 0.0353\ w^{3/4}\ (5.37)^{g}$	90.4	$TDN = 0.0331\ w^{3/4}\ (1.48)^{g}$	91.9

[a] ME and DE are in kcal., all others in pounds.

(1956) and Blaxter and Graham (1955). The design of this trial does not permit a completely valid determination of the net energy of the hay and the concentrate by the simple difference procedure, since the hay was fed alone at only one level. However, the net energy value of the entire ration at each level of feeding can be estimated.

Practically speaking, the amount of feed necessary to maintain energy equilibrium under farm conditions may be credited with a net energy value equal to the animal's heat production when no energy is being consumed. The heat production at zero intake of energy can be estimated by extrapolation of the curve obtained by plotting heat production against metabolizable energy intake, each set of values being reduced to a common basis by the parameter $w^{3/4}$. The value obtained by this extrapolation gives an estimate

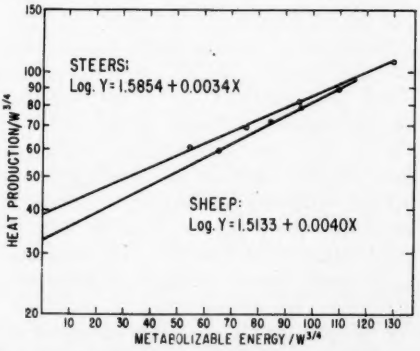

Figure 3. The exponential relationship between daily heat production and metabolizable energy intake in sheep and cattle.

of the net energy required to maintain energy equilibrium, provided the curve adequately describes the relationship between metabolizable energy intake and heat production over the entire range of energy intake. This cannot be proved from the data.

Figure 3 shows the semi-logarithmic plot of heat production per unit $w^{3/4}$ against metabolizable energy intake per unit $w^{3/4}$. The extrapolation of the data to zero intake of energy gives an estimate of the net energy required for maintenance of energy equilibrium in cattle and sheep. The relationship obtained for each species is:

$$\text{Cattle}—38w^{3/4} \qquad \text{Sheep}—33w^{3/4}$$

Values calculated from these relationships are in kilocalories per day when w is in pounds.

The calculation of an equation relating net energy intake to energy gain is not required. Obviously the net energy required for maintenance need only be added to the energy of the gain to obtain an estimate of the total net energy requirement for any rate of energy retention. Equations relating daily net energy intake to daily body-weight gain have been determined.

The linear expression fits the data exceedingly well. In each case the coefficient of determination was over 99.9% when average net energy intake per $w^{3/4}$ was plotted against the average body-weight gain at each level of feeding. The relationships established between net energy intake and body-weight gain given in table 9 were calculated by assuming that the net energy for maintenance can be approximated for either species by one expression, i.e., $35w^{3/4}$.

Discussion

There are several areas of investigation which require some comment before the results of this experiment are discussed. The efficiency with which cattle and sheep digest various feeds is usually considered to be essentially the same. The extensive literature on this subject is reviewed in papers by Cipolloni *et al.* (1951) and Watson *et al.* (1948). Specific differences have been found, but as concluded by Watson *et al.* (1948), ". . . with most feeds these were not of very great magnitude". Furthermore, the average digestion coefficients in most tables of feed composition make no distinction between sheep and cattle. By far the largest number of digestion trials have been conducted with sheep (Cipolloni *et al.*, 1951). The greater accuracy, if any, that might have resulted from separate digestion trials for sheep and cattle would have a doubtful significance for the purpose intended.

Investigations of the digestibility of dietary energy at different planes of nutrition have produced varying results. Some rations show a definite decline in digestibility with increasing intake, while others do not. The reasons for these differences are not fully understood. Blaxter (1950)

reviewed some of the literature on this subject. There was no detectable decline in the digestibility of the ration used in our trial at the higher levels of intake.

A comparison of the dietary energy requirements of different species, as well as different-sized animals within a species, cannot be made on a weight basis alone. It is both necessary and convenient to have some suitable unit of reference for comparing energy requirements. Several values of the exponent of body weight have been used to calculate maintenance energy requirements. These values vary from 0.6 to 1.00 (Blaxter, 1950). Winchester and Hendricks (1953) used 0.66; Armsby and Moulton (1925) 0.715; Brody (1945), 0.73; Klieber *et al.* (1945) 0.75; Axelsson and Eriksson (1953), 0.80; Morrison (1956), 0.87; Haecker (1903) and Gaines (1943), 1.00.

It is now accepted that basal metabolism varies with approximately the 0.73 (Brody, 1945) or 0.75 (Kleiber, 1932, 1947) power of body weight. Whether or not maintenance energy expenditure varies with the same fractional power of body weight as basal metabolism has not been proved. Brody (1945), after a discussion of the theoretical aspects of the proper weight basis to use, presents an interspecies expression for calculating maintenance requirements using $w^{0.73}$ Kleiber (1945) calculated the requirements of dairy cows on the basis of $w^{3/4}$. The National Research Council Committee on Animal Nutrition (1949, 1950, 1956) also uses $w^{3/4}$ as the reference unit for calculating energy requirements. The three-fourth power of body weight was adopted as the unit of reference in this investigation.

Another area that warrants comment concerns the comparative slaughter trial. There is at present no reliable methed for estimating what portion of an animal's apparent weight is due to the contents of the gastrointestinal tract. In this experiment the initial and final weighings were standardized by feeding a maintenance allowance of pelleted hay for 3 days before the weights were taken. The evening feeding of the third day was withheld, and no water was allowed for 14 hours before the weights were taken the following morning. No attempt was made to estimate the weight of the fill. Since the percent body composition as determined by calculation from carcass specific gravity is on an empty-body basis, the procedure used in this investigation assigns to the fill a composition similar to the body composition. Thus, even if the fill of an animal was identical at the original and final weighings, an error could result in the calculated energy retention. Presumably, errors resulting from fill would tend to cancel out of average figures.

There was no difference in the accuracy obtained whether TDN, DE, or ME was used as the measure of food energy for either species (see table 6 and 7). These three measures of food energy are apparently equally reliable for predicting the feeding value of rations similar to those fed in these studies. Practical considerations indicate that the use of digestible

energy provides the most accurate determination that can be made most easily. The desirability of using digestible energy rather than TDN, or calculate the equivalent of TDN, has been advocated by Overman and Gains (1933), Lofgreen (1951), Swift and French (1954), Maynard and Loosli (1956), Swift (1957), and Crampton (1957).

The results of this trial show the agreement between the maintenance requirements of sheep and cattle as calculated from energy retention and from body-weight gain. A study of the constant a (the amount of food energy required for maintenance per unit $w^{.75}$) given in each equation in tables 6 and 7 will reveal the differences in the calculated maintenance requirement per unit $w^{.75}$ for each species, weight gain or energy gain constituting the criterion of response. The requirements for energy maintenance calculated from the sheep data show only a slight difference between the two measures of response. The same comparison for the steer data shows greater differences which are more pronounced with the linear expression. The gains made by the sheep were more nearly of the same chemical composition regardless of the level of feeding. The gains made by the steers showed considerable variation between levels of feeding. Furthermore, the maintenance steers gained slightly in weight but lost energy from body stores. The net effect was that maintenance requirements calculated from simple body weight gain would be too low to maintain energy equilibrium.

There has been much discussion in the literature concerning the relationship obtained by plotting energy intake against retention. All agree that the relationship is curvilinear over the entire range of food intake. Differences of opinion exist as to whether the relationship can or cannot be taken as rectilinear above maintenance (energy equilibrium). The results of this trial do little to elucidate the problem. The data can be reasonably expressed as a linear or an exponential function in the manner chosen to present these results. In general, the steer data were fitted with slightly more accuracy when the exponential expression was used. The sheep data had the opposite tendency; a slightly better fit was obtained with the linear expression. The planes of nutrition covered by the steer data went lower and extended higher than the levels of intake represented by the sheep data. This may partially explain the difference between the two species in this respect.

The maintenance requirements of sheep and cattle on the basis of metabolic body size ($w^{.75}$) appear to be, for practical purposes, equal as estimated by regression of energy intake upon energy gain. Maintenance requirements of steers tend to be higher than those of sheep with either the linear or the exponential estimate. However, considering the variation involved in these estimates, both biological and experimental, the significance of this small difference is questionable. It is suggested, therefore, that the maintenance requirements of sheep and cattle are identical on the basis of $w^{.75}$. Reasonable estimates of this requirement to maintain energy

equilibrium, in terms of the different measures of food energy, can be made from the following relationships:

$$\text{TDN} = 0.036\ w^{3/4}$$
$$\text{DE} = 76\ w^{3/4}$$
$$\text{ME} = 62\ w^{3/4}$$
$$\text{NE} = 35\ w^{3/4}$$

w is in pounds, TDN in pounds per day, and DE, ME and NE are in kilocalories per day.

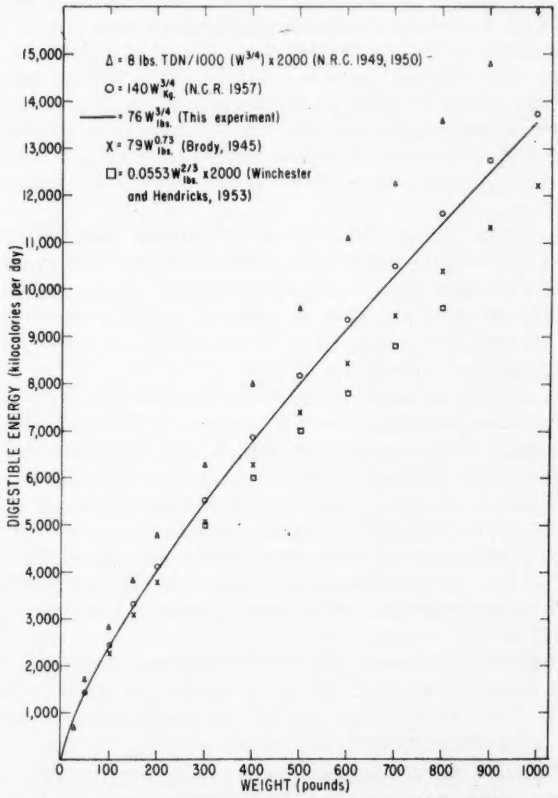

Figure 4. A comparison of standards for the estimation of digestible energy required for the maintenance of sheep and cattle. Standards originally given as TDN were converted to DE by multiplying by 2,000 (Swift, 1957).

Figure 4 is a graphic comparison between various interspecies estimates of DE required for maintenance compared with the estimate derived from this study. The estimates originally given in TDN were converted to DE by considering each pound of TDN to be equivalent to 2,000 kilocalories of digestible energy (Swift, 1957a).

The digestible energy required for the maintenance of energy equilibrium as determined in this investigation is considerably lower than that obtained by using 8 lb. of TDN per 1,000 lb. of body weight. This standard was the basis used by the National Research Council (1949, 1950) for the calculations of the maintenance energy requirements of sheep and cattle. It is slightly higher than the requirements given by Brody (1945) but almost identical with estimates obtained using $140w_{kg.}^{.75}$ (NRC, 1957). The exact origin of this last equation is in doubt. It was credited to Kleiber (1932) by the National Research Council (1957), but no equation for predicting the energy required for maintenance is given in that publication by Kleiber. Apparently the equation was obtained by considering, as did Brody (1945), that twice the basal metabolism—$70w_{kg.}^{.75}$ as given by Kleiber (1932)—would be equivalent to the maintenance requirement in digestible energy.

It is a strange, perhaps a fortuitous, circumstance that twice the basal heat production would equal the requirement of digestible energy for maintenance of an animal. Since basal heat production can be used as an estimate of the net energy required for maintenance, this would mean that 50% of the digestible energy could be considered net energy when used for the maintenance of energy equilibrium.

Brody's (1945) estimates of the TDN required for maintenance are higher than those calculated from the expression $0.036\ w_{lb.}^{.75}$ found in this investigation. It seems inconsistent that Brody's estimates of TDN are higher than those obtained in this investigation while his estimates of digestible energy are lower. This is a direct result of Brody's using the value 1814 kcal. of digestible energy as equivalent to one pound of TDN, a value now considered to be too low (Swift 1957). Brody also used this value, 1814 kcal. per pound of TDN, to convert TDN into metabolizable energy for his net efficiency calculations. (Compare Brody (1945) p. 32, and 98 to p. 475).

That metabolizable energy is equivalent to approximately 80% of the digestible energy of a forage (Swift, 1957) indicates that the expression $140w_{kg.}^{.75}$ (NRC, 1957) which estimates the maintenance requirement in terms of DE would only have to be changed to $112w_{kg.}^{.75}$ to give the estimate in metabolizable energy. Values obtained using this modified expression agree very closely over a range of body weight from 2 to 2000 lb. with values calculated from the relationship $62w_{lb.}^{.75}$ determined in this study. This is perhaps another indication that digestible energy and metabolizable energy are equally reliable measures of food value for ruminants.

The caloric composition of the gains made by the sheep gaining about 0.3 lb. per day was nearly 1700 kcal. per lb. of gain. The steers on the highest level of intake stored approximately 1900 kcal. of energy in each pound of gain. By using the maintenance requirements estimated from the energy retention data and assuming the caloric composition of the gained tissue to be as indicated, it is possible to recalculate the expressions to estimate the energy required for body weight gain. These equations are given in table 9. The less complex, easier to use linear expression is given in each case.

TABLE 8. THE INFORMATION NECESSARY FOR THE DETERMINATION OF NET ENERGY REQUIREMENTS

	Metabolizable energy intake (kcal./day)			Energy retention (kcal./day)	Heat production (kcal./day)	Mean body weight (lb.)
	Hay	Conc.	Total			
Steers						
M	8491	....	8493	—497	8990	784
0.5	8393	3101	11494	897	10597	814
1.0	8356	6356	14712	2005	12707	832
2.0	8485	12210	20695	3560	17135	869
Sheep						
M	1562	...	1562	155	1407	68.3
0.1	1686	410	2096	297	1799	72.8
0.2	1720	791	2511	445	2066	77.6
0.3	1764	1154	2918	547	2371	79.7

An interspecies equation to estimate the energy requirement for maintenance and energy gain of sheep and cattle is possible. It can be seen from table 6 that the slope of the line obtained by plotting the logarithm of energy intake/$w^{\frac{3}{4}}$ against energy gain/$w^{\frac{3}{4}}$ is identical with either species, regardless of the measure of food intake. This would indicate that the net or partial efficiency of food utilization is independent of body size and, therefore, identical in sheep and cattle. Since maintenance energy requirements can also be considered identical, one expression to describe the relationship between energy intake and energy retention is suitable for both species. For example, an estimate of DE for any rate of energy gain for either species can be determined from the expression:

$$DE = 76w^{\frac{3}{4}} (1.03)^{ge/w^{\frac{3}{4}}}$$

It can be demonstrated that for an equation of the type $\phi\ y = ab^x$, x/y would be a maximum when $y = ae$. The function e is a mathematical constant having the approximate value of 2.72. That this type of equation could be reasonably fitted to the data obtained in this experiment, where y is equivalent to energy intake and x to energy gain, with the constant a

representing the maintenance requirement per unit $w^{.73}$ means that maximum efficiency would occur for both species on an energy intake of about 2.72 times the maintenance energy requirement. This level of feeding could not have been obtained with either species on the ration used.

The net energy requirements for maintenance and gain determined in this experiment are in good agreement with published results. Net energy is the ideal measure of the energy value of a ration. It cannot be logically disputed that an expression which actually measures the usefulness of a ration for a particular purpose is to be preferred over one which only indicates a certain potentiality. Net energy values, however determined, are subject to considerable variation from causes of experimental and biological origin. Some of the sources responsible for the variation in net energy values determined by calorimetry might not be associated with net energy values calculated from a well-designed comparative slaughter experiment. Certainly measurements made under actual conditions of practice should be superior to those estimated in short periods of time in an environment totally removed from that existing under farm conditions. Net energy values determined from relatively long experiments under practical conditions would not, however, eliminate such variations as are caused by associative effects of feeds, the influence of the plane of nutrition, or the purpose for which the energy was utilized. These sources of variation are not restricted to net energy determinations, although their effects may be more apparent here.

TABLE 9. EQUATION TO ESTIMATE THE ENERGY REQUIREMENTS OF SHEEP AND CATTLE FOR MAINTENANCE AND WEIGHT GAIN

Sheep	Cattle
$TDN=0.036\ w^{.73}\ (1+2.3g)$	$TDN=0.036\ w^{.73}\ (1+0.57g)$
$DE=\ 76\ w^{.73}\ (1+2.4g)$	$DE=\ 76\ w^{.73}\ (1+0.58g)$
$ME=\ 62\ w^{.73}\ (1+2.5g)$	$ME=\ 62\ w^{.73}\ (1+0.60g)$
$NE=\ 35\ w^{.73}\ (1+1.8g)$	$NE=\ 35\ w^{.73}\ (1+0.45g)$

The results of these studies indicate a possible application of this modified comparative slaughter technique to a wide variety of nutritional investigations where energy retention would be a more significant measure of response than weight gain.

Summary

The energy requirements of sheep and cattle for maintenance and gain have been investigated, 64 sheep and 39 cattle serving as the experimental animals. The response to different levels of energy intake was measured by body weight gain and by energy retention. The data were analyzed by linear and exponential regression of energy intake, expressed as TDN, DE,

and ME, on these two measures of response. Net energy requirements were also determined.

Energy retention was estimated by a modification of the comparative slaughter technique. This technique was simplified by making use of the known relationships which exist among the major chemical components of the animal body. The specific gravity of the dressed animal carcass was the only measure necessary from which body composition could be estimated. The relationships necessary for estimating body composition of cattle from carcass specific gravity were available in the literature. To apply this method to sheep the necessary relationships were established from data found in the literature and by the chemical analysis of 20 sheep carcasses.

The following relationships were established:

1. Percent carcass fat = 556.6 — 505.0 × (carcass specific gravity)
2. Percent whole body fat = 0.8817 × (carcass fat) — 1.520
3. Percent whole body water = 76.89 — 0.8384 × (percent whole body fat)
4. The fat-free dry matter is 80.7% organic matter (protein)

All whole body values are on a wool-free empty-body basis.

The estimated daily energy requirements of sheep and cattle for maintenance of energy equilibrium can be obtained in terms of the different measures of food energy by the following expressions:

$$TDN = 0.036w^{\frac{3}{4}}$$
$$DE = 76w^{\frac{3}{4}}$$
$$ME = 62w^{\frac{3}{4}}$$
$$NE = 35w^{\frac{3}{4}}$$

TDN and weight (w) are in pounds. DE, ME, and NE are in kilocalories.

The partial efficiency of food utilization was found to be independent of body size. Therefore, one relationship between energy intake and energy gain will express the energy requirements of sheep and cattle. For example, an estimate of DE for any rate of energy gain in either species can be determined from the expression:

$$DE = 76w^{\frac{3}{4}} (1.03)^{g_e/w^{\frac{3}{4}}}$$

where g_e is gain in kilocalories.

Other less complex, easier to use relationships between energy intake and energy retention or body weight gain were established from the data. These equations enable the estimation of the energy required for any rate of energy retention or weight gain in each species.

In estimating energy requirements, TDN, DE, and ME can be used as the measure of food energy with equal accuracy. This is interpreted as indicating an equality between these measures of food energy for expressing the energy value of a ration.

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COMPARISON OF METHODS FOR ESTIMATING THE FEED USED FOR GROWTH AND MAINTENANCE OF BEEF CALVES [1]

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THE efficiency of utilizing feed by growing beef calves is frequently reported on the basis of the number of pounds of feed (TDN, etc.) consumed per pound or hundred-weight of gain. This method may have some advantages when comparing calves, or groups, especially if they are fed the same ration and are of similar weights and ages during the feeding period. One disadvantage of the method may be that all of the feed is charged against gain. Slowly gaining animals are sometimes charged with large amounts of feed per unit gain; the requirements for maintenance are only implied. Apparently it is not possible at the present time to ascertain the requirements for the maintenance of growing beef calves by direct methods. Indirect approaches to the problem through the use of regression techniques have been made by Brody (1945), and Winchester and Hendricks (1953).

The objectives of the present study were (1) to study the relationships among consumed energy, average body weight, and gain during feeding periods by use of equations 5 and 6 of Winchester and Hendricks (1953); (2) to compare the efficiencies of the two equations; and (3) to study the relative value of computing the energy consumed in terms of total digestible nutrients (TDN) and net energy (NE). Average body weight was used as a measure of maintenance. Studies of the relationships and the computation of values for the constants of the equations from data of different groups of calves may lead to the development of new methods which might be of assistance in the selection of breeding stock. Studies relative to the efficiency of different equations and methods of estimating consumed energy may result in lessening the labor in the future.

Materials and Methods

Angus and Hereford heifer and steer calves born during the four years 1949–1952 were individually full-fed from weaning to 370 days of age.

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[3] This manuscript is based primarily on the M.S. thesis of this author.

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The number of calves per weaning age, sex, and breed group was as follows:

	Angus		Hereford	
Weaning age	heifer	steer	heifer	steer
90 days	14	23	8	4
180 days	8	20	6	2

The calves used by Green and Buric (1953) were the 1949–1951 calves of this present study. The method for assigning an individual to a weaning age group, feeding and management practices, composition of the rations, and weighing schedules were reported in detail by Green and Buric (1953). Their methods were, briefly, as follows: Some calves were assigned to a weaning age group on the basis of random choice and the others were placed into a group opposite to that of a previously used maternal half-sib or full-sib. U. S. No. 1 alfalfa hay was fed during the age period of 90 to 180 days and U. S. No. 2 alfalfa hay from 180 to 370 days of age. Chopped hay and a grain mixture were fed free-choice to the 1949–1951 calves. The 1952 calves were fed the hay ground and mixed with the grain mixture in a ratio of 1:3, essentially the same ratio which was consumed by the calves fed on the free-choice basis. The TDN values for concentrate mixtures were computed from the values for each ingredient as given by Morrison (1948). Values for hays were found by comparing the chemical analyses of the hays to those given by Morrison (1948).

Net energy values for the components of the diet were calculated by the method used by Irvin *et al* (1951) and the therms of NE per ton of mixed feed were estimated from the proportions of the ingredients.

The data were analyzed by use of equations (5) and (6) of Winchester and Hendricks (1953). Equation (5) is $f=aw^be^{kg}$ where f= average daily intake of energy, in pounds of TDN or therms of NE.

w=average body weight, in pounds, during the feeding period.

g=average gain per day, in pounds.

e=2.71828, the base of the Naperian logarithm system.

a=calculated constant: a refers to the pounds of TDN or therms of NE required for maintenance per day per pound of body weight raised to the b power.

b=calculated constant; b denotes the rate at which requirements for maintenance change relative to changes in body weight.

k=calculated constant, used with g to estimate energy associated with gain.

aw^b represents the estimated requirement of energy for maintenance.

e^{kg} represents the estimated requirement of energy for gain.

Equation (6) is $f=aw^b(1+kg)$ where f, w, and g represent the same items as given for equation (5). Because of the impossibility of calcu-

lating values for all three constants, a, b, and k, of equation (6), values of b found for equation (5) were used for equation (6) following the method and assumption of Winchester and Hendricks (1953). The segment aw^b represents the same information as given for equation (5) and kg represents the estimated amount of energy required for growth.

Results and Discussion

Reference to the calves and feeding periods will be made in terms of age in order to maintain uniformity relative to the previous study by

TABLE 1. AVERAGES AND STANDARD DEVIATIONS OF VARIABLES BY FEEDING AGE PERIODS

Variable and Statistic	Inclusive days of age of feeding periods		
	90 to 202	90 to 370	202 to 370
No. of calves	49	49	85
Av. wt. for period [a]			
Mean	285	424	513
Standard deviation	29.9	41.9	52.2
Gain per day [a]			
Mean	1.46	1.58	1.66
Standard deviation	0.24	0.19	0.23
TDN per day [a]			
Mean	5.28	7.36	8.82
Standard deviation	0.67	0.82	1.01
NE per day [b]			
Mean	4.99	6.97	8.32
Standard deviation	0.65	0.81	1.00

[a] Statistics are in terms of pounds.
[b] Statistics are in terms of therms. TDN refers to total digestible nutrients and NE refers to net energy.

Green and Burdic (1953) and to later studies. Weight, not age, was one of the variables used in this present study. There was no over-lapping of average weight during the feeding periods of 90 to 202 and 202 to 370 days of age. On that basis, the two periods may be considered distinct relative to weight and age also. These two factors were confounded and age effects, as such, may or may not have been operating concomitantly with differences in weight.

The means and standard deviations of average weight per period, gain per day, and TDN and NE consumed per day for the various feeding periods are presented in table 1.

Averages, values computed for the constants, and standard errors of estimate in terms of f are presented in tables 2 and 3 for equations (5) and (6), respectively. Comparisons made between measure of energy within feeding period and equation indicate that the values of a were

TABLE 2. STATISTICS IN REFERENCE TO EQUATION (5)
$f=aw^be^{kg}$

Statistic[b]	Energy units and inclusive days of age of feeding periods					
	TDN[a]			NE[a]		
	90 to 202	90 to 370	202 to 370	90 to 202	90 to 370	202 to 370
Mean log f	0.719	0.864	0.942	0.695	0.841	0.917
Log a	—0.534	—0.872	—1.142	—0.570	—0.897	—1.194
a	0.293	0.134	0.072	0.269	0.127	0.064
b	0.426	0.607	0.727	0.431	0.600	0.725
Mean log w	2.452	2.625	2.708	2.452	2.625	2.708
k	0.329	0.207	0.159	0.328	0.237	0.204
g[c]	1.458	1.576	1.664	1.458	1.576	1.664
Standard error of estimate[d]	0.384	0.440	0.527	0.403	0.491	0.536

[a] TDN refers to total digestible nutrients; NE refers to net energy.
[b] For purposes of computation, the equation was re-expressed as log f=log a+b log w+kg log e.
[c] Mean daily gain, in pounds.
[d] In terms of pounds of TDN or therms of NE.

higher for equations based on TDN than for those involving NE; however, a direct comparison is not valid in this instance as TDN is expressed in pounds and NE in therms. Approximating from the information by Moore *et al* (1953), the ratio of units of TDN:NE should be about 1:0.9 for the diet used. The ratios of a values, on the basis of the above comparisons, were found to fluctuate around the 1:0.9 ratio. Ratios relative to equation (6) were more uniform than those from equation (5). On a within measure of energy and feeding period basis, the a values were higher for equation (5) than for equation (6). Inasmuch as the b values were the same for both equations for any specific feeding period and measure of energy, use of equation (5) would result in a higher estimate for the requirement for maintenance of a given body weight. The difference would be least for the 202–370 days of age feeding period.

TABLE 3. STATISTICS IN REFERENCE TO EQUATION (6)
$f=aw^b(1+kg)$

Statistic[b]	Energy units and inclusive days of age of feeding periods					
	TDN[a]			NE[a]		
	90 to 202	90 to 370	202 to 370	90 to 202	90 to 370	202 to 370
Mean f	5.278	7.360	8.816	4.992	6.971	8.318
Mean f ÷ antilog (b) (log w)	0.476	0.187	0.094	0.436	0.185	0.090
a	0.251	0.125	0.070	0.231	0.116	0.061
k	0.615	0.310	0.210	0.608	0.380	0.289
Standard error of estimate[c]	0.378	0.435	0.523	0.380	0.419	0.506

[a] TDN refers to total digestible nutrients; NE refers to net energy.
[b] For purposes of computation, the equation was re-expressed as $f/w^b=a+akg$. The respective values of b of equation (5) were used in connection with equation (6).
[c] Statistics refer to pounds of TDN or therms of NE. Respective means for g are same as given in table 3.

The magnitudes of the b constants were essentially the same within feeding age periods for the equations based on TDN and NE. A rather low value, 0.43, was found for the calves of the lightest weight. The 0.73 values for the 202 to 370 day age group agree quite closely with the values of 0.75 proposed by Kleiber (1932) and 0.73 of Brody (1945) for mature individuals and the 0.67 found by Winchester and Hendricks (1953) relative to their beef calves.

The calves of the latter authors did not coincide with any particular group in this present study. Their calves were (a) approximately 4⅓ months old at the start of the trial, (b) on trial essentially 4.6 months, (c) about 6⅔ months in average age on trial, (d) of an average weight of 309 lb. while on trial, (e) gaining an average of 0.85 lb. per day, and

TABLE 4. STANDARD ERRORS OF ESTIMATE [a]

	Estimates for maintenance			Estimates for growth		
	Inclusive days of age of feeding periods					
Items	90 to 202	90 to 370	202 to 370	90 to 202	90 to 370	202 to 370
Eqn. 5 TDN [b]	0.234	0.312	0.396	0.118	0.081	0.077
Eqn. 6 TDN	.195	.287	.384	.135	.086	.079
Eqn. 5 NE	.234	.287	.368	.125	.087	.087
Eqn. 6 NE	.197	.255	.342	.142	.094	0.90

[a] For explanation of methods, see text.
[b] TDN refers to total digestible nutrients, units in pounds; NE refers to net energy, units in therms.

(f) fed to varying degrees in respect to maintenance, the gain per day ranging from −0.226 to + 2.235 lb. The b value found by them was 0.67, being between the b values found in this study relative to the calves of the 90 to 370 and 202 to 370 days of age feeding periods. The fiducial limits (5% level) of the b values of this study were, in order of the columns of table 2, ± 0.22, 0.27, 0.16, 0.24, 0.28, and 0.17. Thus, the 0.67 of Winchester and Hendricks (1953) fell well within the fiducial limits of the values found in this study.

Values found for k decreased in size from the lightest to heaviest calves and were in reverse order relative to the average gain per day in respect to the different feeding periods. The values were of about the same proportional difference between the two equations, within feeding period and measure of energy, as those found by Winchester and Hendricks (1953).

Two methods of comparison were used to study the exactness of estimate from use of the two equations. Standards errors of estimate for each equation when compared within feeding age period and measure of energy, tables 2 and 3, indicated that equations (5) and (6) were essentially of equal value when TDN was used as a measure of energy. The largest difference was 0.006 lb. Equation (6) had lower standard errors of estimate associated with it when energy was measured as NE; differences varied from 0.023 to 0.072 therms.

The second method used for comparison was based on that used by Winchester and Hendricks (1953) and their terminology was followed. For equation (5), $f=aw^be^{kg}$, "computed" maintenance requirements were estimated by use of aw^b and "observed" requirements by use of $\frac{f}{e^{kg}}$. An estimate was made each way for each calf. The difference of "observed" minus "computed" was determined for each calf. A "standard error of estimate" of $\frac{f}{e^{kg}}$ in respect to aw^b was then computed using the formula

$$\sqrt{\frac{\Sigma\,(o-c)^2}{N - \text{no. of variables}}}.$$

Similar calculations were made in regard to equation (6), $f=aw^b\,(1+kg)$, using aw^b and $\frac{f}{(1+kg)}$. For gain, estimates were made by using e^{kg} and $\frac{f}{aw^b}$ for equation (5) and $(1+kg)$ and $\frac{f}{aw^b}$ for equation (6). Comparisons of these "standard errors of estimate" (table 4) between equations within measure of energy and feeding age period showed smaller values for equation (6) than (5) for estimates of "maintenance". In respect to gain, the two equations were essentially equal except for the 90 to 202 days feeding period where smaller values were found relative to equation (5). These results are, in general, in agreement with those of Winchester and Hendricks (1953).

The above indicates that for future work equation (6) might be used in preference to equation (5); however, a few problems arise. Values for the constants for equation (5) must be calculated before equation (6) may be used because of the impossibility of solving for all three constants for equation (6). The value for one constant from equation (5) has to be "borrowed" from equation (5) for use in equation (6), as was the value for b in this study, following the practice of Winchester and Hendricks (1953). Consideration should be given to the validity of using a constant from equation (5) for equation (6) as well as the worth of any added accuracy secured from using equation (6) relative to the extra work involved.

A review of the information found in this study indicates that, under the conditions involved, computation of the feed eaten in terms of TDN or NE leads to essentially the same results.

Summary and Conclusions

Relationships among (a) consumed energy, expressed as total digestible nutrients or net energy; (b) average body weight, as a measure of "maintenance"; and (c) gain were studied by use of two equations. One equation was $f=aw^be^{kg}$ and the other was $f=aw^b\,(1+kg)$ where f=

average daily intake of energy, w= average body weight during the feeding period (in pounds), and g= average daily gain (in pounds) and a, b, and k were constants for which values were calculated. The relative value of the two equations was also studied. Growing steer and heifer beef calves which were individually full-fed from weaning, 90 or 180 days of age, to 370 days of age were the source of the data.

Values for constant b were found to be 0.4, 0.6 and 0.72 for the feeding age periods of 90 to 202, 90 to 370, and 202 to 370 days, respectively. Standard errors of estimate tended to be lower for equation (6) than for equation (5); however, use of equation (5) might be preferred because of the assumptions and added work associated with equation (6). Calculation of consumed energy in terms of TDN or NE appeared to be of about equal value under the conditions of this study.

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EFFECT OF FEEDING DIFFERENT COMBINATIONS OF SOFT PHOSPHATE WITH COLLOIDAL CLAY AND DICALCIUM PHOSPHATE WITH AND WITHOUT ADDED FLUORINE FOR GROWING-FINISHING SWINE [1]

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SOFT phosphate with collodial clay, hereafter referred to in this paper as colloidal phosphate, is the dried washings of the raw rock phosphate industry. This phosphatic product contains approximately 9% phosphorus and 1.5% flourine.

Gerry *et al.* (1947) reported that colloidal phosphate fed to chicks at the rate of 2.5% of the total ration resulted in satisfactory calcification but lowered growth rates. He attributed the inhibition to the fluorine content. Grau and Zweigart (1953) compared colloidal phosphate to bone meal and tricalcium phosphate as sources of phosphorus for chick diets and observed a much lowered growth rate. Addition of 0.035% sodium fluoride to a ration containing tricalcium phosphate did not affect growth rate. He concluded that the fluorine content of the colloidal phosphate was not responsible for depressed growth rate.

Gobble *et al.* (1956) reported satisfactory results from using colloidal phosphate in ration of growing-finishing pigs at levels of 0.5% for periods up to 180 days, 1% for periods up to 131 days, 2% for periods up to 161 days and 4%, for a period of 117 days. Chapman *et al.* (1955) observed that feeding colloidal phosphate to growing-finishing swine resulted in decreased rate of gain, feed efficiency and breaking strength of femurs, as compared to steamed bone meal or dicalcium phosphate. Also there was a significant increase in ash and fluorine content of the femur but no significant difference in phosphorus content of bone ash or blood serum when two levels of colloidal phosphate were fed which provided 0.025 and 0.045% fluorine in the total ration. The pigs on the higher colloidal phosphate levels ate significantly less feed and required significantly more feed per unit of gain than pigs fed dicalcium phosphate in a complete ration.

Johnson *et al.* (1953) studied combinations of colloidal phosphate and bone meal in rations for young chicks. Results indicated that colloidal phosphate may be used to supply part of the phosphorus needs of the

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young chick. However, they concluded that not more than 2% of the total ration should be from this phosphorus source.

The purposes of the research reported herein were (1) to study the effect of feeding different combinations of colloidal phosphate and dicalcium phosphate in growing-finishing swine and (2) to differentiate the response from the two sources of phosphorus as affected by fluorine level.

Experimental

Fifty-four Poland China X Landrace X Duroc crossbred pigs averaging 75 lb. body weight were selected and confined to enclosed concrete-floored pens. Prior to the experiment the pigs were wormed with a 1% cadmium oxide ration and they were sprayed with a solution of benzene hexachloride. Feed and water were provided *ad libitum*. The pigs were removed from the experiment at a pen average weight per pig of 200 lb. The average number of days on experiment was 78 with a range from 56 to 112 days.

The nine experimental ration treatments consisted of five different combinations of dicalcium phosphate and colloidal phosphate added to a

TABLE 1. COMPOSITION OF EXPERIMENTAL RATIONS [a]

	Ratio of phosphorus source				
Dicalcium phosphate	100	75	50	25	0
Soft phosphate with colloidal clay	0	25	50	75	100
Ingredients					
Gr. yellow corn (8.9% protein) lb.	83.00	82.85	82.60	81.95	81.00
Solv. soybean oil meal (47.3% protein)	12.00	12.00	12.00	12.25	12.40
Calcium carbonate [b] lb.	.70	.55	.40	.20	—
Dicalcium phosphate [c] lb.	1.70	1.50	1.20	.75	—
Colloidal phosphate lb.	—	.50	1.20	2.25	4.00
Iodized salt lb.	.50	.50	.50	.50	.50
Trace minerals [d] lb.	.10	.10	.10	.10	.10
Vitamin premix [e] lb.	2.00	2.00	2.00	2.00	2.00
Sodium fluoride added [f] gm.	43.10	37.70	30.10	18.80	—
Fluorine, % of ration	0.0428	0.0428	0.0428	0.0428	0.0428
Supplied by P. carrier	0.0020	0.0072	0.0143	0.0250	0.0428
Added in sodium fluoride	0.0408	0.0356	0.0285	0.0178	—

[a] 14% protein ration changed to 10% at 150 lb. body weight by varying the proportions of corn and SBOM.

[b] Calcium carbonate level was adjusted in the 14 and 10% protein rations to maintain calcium levels of 0.8 and 0.7% respectively.

[c] Dicalcium phosphate and colloidal phosphate levels were adjusted in the 14 and 10% protein rations to maintain phosphorus levels of 0.6 and 0.5% respectively.

[d] Contributed the following ppm to the ration: Co, 1.6; Cu, 4.8; Fe, 70; Mn, 56.8; K, 7.5; Zn, 17.6.

[e] Contributed the following per lb. of total ration; Calcium pantothenate, 5 mg.; choline chloride, 400 mg.; niacin, 15 mg.; riboflavin, 1.5 mg.; terramycin, 10 mg.; vitamin A, 3,000 I.U.; vitamin D_2, 400 I.U.; and vitamin B_{12}, 5 mcg. in a soybean oil meal carrier.

[f] Sodium fluoride was added to 4 rations to raise the fluorine level to that supplied in the ration treatment where colloidal phosphate was used as the *only* supplemental phosphorus source. Five rations had no sodium fluoride additions.

fortified corn-soybean oil meal ration and four rations with sodium fluoride added in amounts sufficient to produce fluorine levels equal to the level in the ration containing only colloidal phosphate as supplemental phosphorus. Corn and soybean oil meal were varied to provide a level of 14% protein from initial to 150 lb. body weight and 10% protein from 150 to 200 lb. Composition of the rations and varying ratios of phosphorus source are presented in table 1. On the basis of previously analyzed sources of phosphate, the range of fluorine levels was 0.0020 to 0.0428% in the 14% protein ration and 0.0016 to 0.0332% in the 10% protein ration. The Sub-

TABLE 2. ANALYSIS OF VARIANCE PLAN AND OBSERVED MEAN SQUARES FOR AVERAGE DAILY GAIN AND FEED REQUIRED PER POUND OF GAIN

Source of variation	D.F.	Mean squares	
		Daily gain	Feed/gain
Replications	2	0.0552	0.1024
Levels of colloidal phosphate (Fluorine not equalized)	4		
Linear	1	0.6221*	0.7315*
Quadratic	1	0.0173	0.0066
Remainder	2	0.0036	0.0120
Levels of colloidal phosphate (Fluorine equalized)	4		
Linear	1	0.0012	0.0048
Quadratic	1	0.0707	0.0740
Remainder	2	0.0446	0.2527
Error	16	0.0279	0.0766

* Statistically significant (P=0.05 or less).

committee on Fluorosis Problems (1955) lists 0.007 to 0.010% fluorine in the total ration as the maximum safe level of fluorine intake when sodium fluoride or other soluble fluorides are the source of fluorine. If phosphatic limestone or rock phosphate is the sole source of fluorine the recommended safe level is 0.010 to 0.020% fluorine. Equal quantities of dicalcium phosphate and colloidal phosphate were obtained from three different producers of each and the products of each were blended before incorporation into the experimental rations as a precautionary measure against heterogeneity of the material from any one source.

A randomized block design in three replications was used for this study. The ration treatments were allotted to the pens at random within each replication and the pigs were randomly allotted from outcome groups of initial weight within sex. One barrow and one gilt were confined to each pen and the pen of two pigs was then employed as the experimental unit in the statistical analysis of the ration treatment data. The pen means on a per pig basis for daily gain and feed per lb. of gain were analyzed according to

the analysis of variance plan presented in table 2. All references in the text to statistical significance pertain to a probability level of 5% or less.

Results and Discussion

Summaries of daily gain, daily feed and feed per lb. of gain are graphically presented in figure 1.

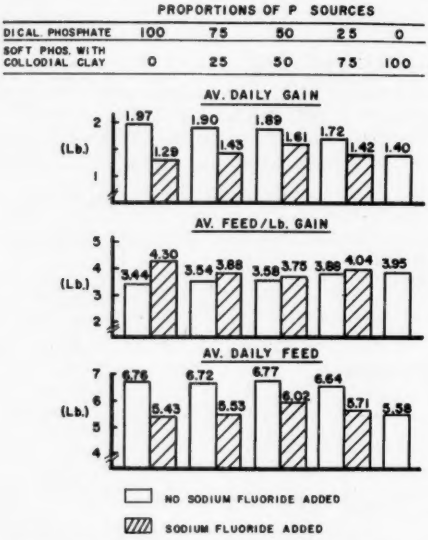

Figure 1. Summary of average daily gain, feed required per pound of gain and feed consumed per day.

Analysis of the effect of changing the supplemental phosphorus source in the ration from 100% dicalcium phosphate to 100% colloidal phosphate, in the absence of sodium fluoride, showed a statistically significant linear decrease in gain and feed efficiency. These observations are similar to those observed in previous research at this station (Chapman *et al.*, 1955). These results were obtained with an all-plant protein ration (corn and soybean oil meal) which contained a low level of phosphorus and required more supplemental phosphorus than would be the case if the ration had contained some animal protein ingredients. This could explain the differences between these results and the report of Johnson *et al.* (1953) who showed that chicks performed satisfactorily when colloidal phosphate was included up to but not over 2% of the diet.

When the quantities of added sodium fluoride were decreased (increased proportions of colloidal phosphate) rate of gain, daily feed intake, and feed efficiency tended to peak at the 50:50 combination of dicalcium phosphate and colloidal phosphate. These apparent quadratic responses failed to reach statistical significance; however, these trends do suggest that factors other than the fluorine content may be contributing to the decreased performance with increasing levels of colloidal phosphate. Phosphorus availability or added inert material may account for a part of poorer performance of pigs fed diets containing high levels of colloidal phosphate. The Subcommittee on Fluorosis Problems (1955) states that fluorine in the form of sodium fluoride is believed to be more toxic than the fluorine of rock phosphate.

Both the 0.025 and the 0.045% levels of fluorine exceed the recognized tolerances of fluorine for swine based on recommendations of the Subcommittee on Fluorosis Problems (1955). No gross symptom of fluorine toxicity was noted in any of the pigs. Results at this station (Chapman *et al.*, 1955 and these data) are not contradictory to the work of Gobble *et al.*, (1956) as far as symptoms of gross abnormalities from feeding colloidal phosphate are concerned. However, rate of gain, feed efficiency, and feed intake were markedly depressed by increasing levels of colloidal phosphate in these studies; though the workers at the Pennsylvania Station did not observe such depressions.

Further work on this ingredient to explain its action might readily be accomplished by checking the question of added inert bulk. The report by Hobbs *et al.* (1954) indicating that aluminum compounds will alleviate the toxic effects of fluorine, also suggests another technique for studying the effects of fluorine in colloidal phosphate on animal performance.

Summary

Fifty-four crossbred pigs were fed from 75 to 200 lb. body weight to study the effects of (1) varying proportions of soft phosphate with colloidal clay (colloidal phosphate) and dicalcium phosphate as sources of supplemental phosphorus and (2) adding sodium fluoride to the ration to give a calculated fluorine content in the ration equivalent to that when colloidal phosphate supplied 100% of the supplemental phosphorus.

Increasing the levels of colloidal phosphate from 0 to 4.0% of the ration (0 to 100% of the supplemental phosphorus) resulted in a statistically significant linear decrease in rate of gain and feed efficiency when no sodium fluoride was added to the rations.

There was an indication of a factor or factors other than fluoride in the colloidal phosphate which contributed to the depressing effect of colloidal phosphate on gains and feed conversion.

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BLOOD FAT LEVELS IN GROWING-FINISHING SWINE AS INFLUENCED BY SEX, AGE, BREED AND RATION [1, 2]

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ALLEN (1938) found blood fat levels varied with stage of reproduction and lactation in dairy cattle. Kunkel *et al.*, (1953) reported serum alkaline phosphatase varied with age and breed and under certain conditions was significantly associated with feed efficiency and feed intake in beef cattle. Dinusson *et al.*, (1950) found that spaying decreased rate of gain and feed efficiency but increased the blood lipid level in beef heifers.

Perry *et al.* (1953) reported limited data on the influence of ration supplements on blood fat levels in swine. Self (1954) reported a tendency for blood fat levels to be associated with certain reproductive traits in swine. Bowland and Hironaka (1957) observed a relationship between blood lipid levels in pigs and certain carcass characteristics. Morrow *et al.*, (1956) had previously studied this relationship but found that environmental temperature and time of day were influencing factors. These studies suggest that blood fat levels may provide a relatively simple means of estimating several traits of economic importance in the live hog without the necessity of sacrificing the animal. However, it will be necessary to develop a greater knowledge of the factors associated with or thought to influence blood fat levels in swine before useful relationships can be established.

This report deals with some of the effects of age, sex, breed, protein source, protein level, and the feeding of an antibiotic on blood fat level and its association with rate of gain in growing-fattening swine.

Materials and Methods

Twenty-five Chester White gilts, 19 Chester White barrows, 13 Poland China gilts and 6 Poland China barrows, approximately 9 weeks of age, were stratified into groups according to weight, sex and breed, and then allotted randomly from within strata to eight lots. Lots 1 through 4 were self-fed a corn, alfalfa meal and peanut meal rations. Lots 5 through 8 were self-fed a corn, alfalfa meal, soybean meal, dried brewers yeast, and dried skim milk ration. All lots received mineral and vitamin supplements in sufficient quantity to meet the minimum requirements as recommended

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by the National Research Council (1953). Lots 2, 4, 6 and 8 received 9 mg. of chlortetracycline per lb. of ration. Lots 1, 2, 5 and 6 were started on a ration containing approximately 12% crude protein and Lots 3, 4, 7 and 8 were started on a 16% protein ration. As the pigs matured the level of protein was lowered accordingly to allow Lots 1, 2, 5 and 6 to finish on a 10% ration and the other lots to finish on a 12% ration. The calculated fat content of the various rations ranged from 3.5% to 4.2%.

Three pigs were removed during the course of the study. (Two had severe parakeratosis and one became paralyzed). A blood sample consisted of 15 to 20 ml. of whole blood from the area of the vena cava. The samples were oxalated to prevent coagulation, centrifuged and the plasma drawn off and stored at 5–10° F. until the blood-fat analysis could be completed.

Initial samples were obtained from all pigs on July 13, 1954, when the ages ranged from 120 to 129 days and the pigs had been on their respective rations for approximately 2 months. Subsequent samples were taken at 3-week intervals until they reached a slaughter weight of 210 lb. Some hogs had reached slaughter weight by September 14 (date of taking of 4th sample); therefore, only the first four samples for each animal were used so that the influence of environment factors would be uniform for all groups. The order of bleeding of lots was varied between times and the order of individuals within lots was at random. Samples were taken in the afternoon between 1 p.m. and 3 p.m. The daily barn routine allowed a uniform lapse of time between the beginning of morning activity and the taking of samples. The average weight of all pigs was 92.2 lb. and 170.6 lb. on July 13 and September 14, respectively, for an overall average daily gain of 1.24 lb.

Fat content of the blood was determined by the method of Allen (1938). Duplicate determinations were made and an average of the two was used.

Data were examined by the analysis of variance and the analysis of covariance. (Snedecor, 1951)

Results and Discussion

Disproportionate observations in the various sub-groups prevented the usual analysis of variance. Therefore, a preliminary statistical analysis was performed by selecting one pig at random to represent each sub-group. This preliminary analysis of variance as well as a gross examination of the sub-group means including all animals for all groups indicated there was no interaction of the factors studied. In subsequent tests of significance, all animals in a sub-group were included. The means for barrows and gilts were almost identical as were the means of the two groups receiving protein from different sources. A test of each two factors indicated that there was no significant difference in blood fat level between the groups receiving protein from different sources or between the barrows and gilts: thus, the protein-source groups were pooled and the data for barrows and gilts were

pooled. Further tests indicated the 177 mg. % level of the Chester White did not differ significantly from the 174 mg. % level of the Poland China. However, the 185 mg. % level of the 12% protein group was significantly greater ($P<0.01$) than the 166 mg. % level of the 16% protein group. The 180 mg. % level of the no-antibiotic group was significantly greater ($P<0.05$) than the 172 mg. % level of those receiving antibiotic (table 1). These differences indicate that blood fat levels can be significantly altered

TABLE 1. THE EFFECTS OF BREED, PROTEIN LEVEL, AND THE FEEDING OF AN ANTIBIOTIC ON THE FAT LEVELS IN PIG BLOOD PLASMA

Protein in ration, %	Breed	Antibiotic in ration	Number of blood fat samples	Fat in blood plasma, mg. per 100 ml.
12	Chester White	Yes	40	178
		No	44	194
12	Poland China	Yes	24	187
		No	20	179
12	Both Breeds	Yes	64	181
		No	64	189
16	Chester White	Yes	36	163
		No	44	172
16	Poland China	Yes	16	155
		No	16	169
16	Both Breeds	Yes	52	161
		No	60	171
	Total or Average			
12	—	—	128	185**
16	—	—	112	166
—	Chester White	—	164	177
—	Poland China	—	76	174
—	—	Yes	116	172
—	—	No	124	180*
	Over-all Total and Average		240	176

* Probability of 0.05.
** Probability of 0.01.

by antibiotics and by ration protein level and should be taken into account whenever the fat level of swine blood is being reported.

The correlation coefficient between age and weight within pigs was highly significant ($r=0.93$, $P<0.01$). The association of blood fat level and age at the time of sampling ($r=0.40$) and blood fat level and weight ($r=0.42$) were both highly significant (both, $P<0.01$). Age and weight were considered as independent variables and blood fat level as the dependent variable and standard partial regressions established in order better to understand these relationships. The standard partial regression within pigs of blood fat level on age with weight held constant was $b'=0.09$ and

for blood fat level on weight with age held constant was $b'=0.36$. This indicates that the association of age and blood fat level within pigs is negligible if the influence of weight is held constant and that age is only one-fourth as important as weight as an indicator of blood fat levels.

The total gain in pounds per pig from July 13 to September 14 was correlated with the average of the four blood fat determinations for each pig over the same period as a check on the association of growth and average level of fat in the blood. The gross correlation coefficient was positive and non-significant ($r=0.22$), agreeing closely with the value reported for fasted pigs ($r=0.23$) by Bowland and Hironaka (1957). However, this gross coefficient is a mixture of the variance within and between treatment groups and makes it necessary to examine these sources to obtain a meaningful coefficient. Therefore, the association of total gain during the test period with the average blood fat level was determined by establishing a correlation coefficient from the sub-group sums of squares and sums of cross products; i.e., within breeds, protein levels and antibiotic groups. The correlation coefficient obtained in this manner ($r=0.40$; $P<0.01$) indicated that the fastest gaining pigs (within groups) had the higher blood fat values.

The highly significant association of blood fat level with weight (within pig $r=0.42$) and the highly significant association of the total gain of each pig with the average of the four blood fat determinations ($r=0.40$) and the low association of age with blood fat levels within pigs ($b'=0.09$) when the influence of weight is held constant, indicates that on the average the fastest gaining individuals within the sub-groups as well as the heavier pigs at any given age will probably have the highest blood fat values. However, the fastest gaining and thus the heaviest test groups reacted in the opposite manner. For example, the 12% protein groups gained an average of 1.08 lb. per pig and averaged 185 mg. % blood fat as compared to 1.37 lb. and 166 mg. % for those receiving 16% protein. The trend is still evident but to a much smaller degree in the case of antibiotics. Those groups receiving antibiotics gained an average of 1.25 lb. and averaged 172 mg. % as compared to 1.20 lb. and 180 mg. % for those not receiving antibiotics. Thus the group on a low level of protein gave less gain but more blood fat and the no-antibiotic group had less gain and more blood fat.

Perry *et al.* (1953) reported that 185-lb. pigs had a mean blood fat level of 151 mg. % when fed a control ration containing 18% protein. Pigs fed this same basal ration plus an antibiotic or a surfactant had 160 mg. % and 170 mg. %, respectively. Considering only those receiving antibiotics and 16% protein in the present study, the mean level of 161 mg. % was similar to the 16 mg.% level of antibiotic-fed pigs on an 18% starting ration reported by Perry *et al.* (1953). They observed a nonsignificant decrease in the mean blood fat level when pigs were fed antibiotics whereas a significant increase was observed in the present study. Canadian workers, Bowland and Hironaka (1957) reported a level of 139 mg. % in non-fasted 100-lb. York-

shire pigs. This level and that reported by Perry *et al.* 1953) is lower than the 176 mg. % mean level of all the pigs in the present study. The rate of gain in both of the previous reports was greater than in this study and it should be recalled that in the present study the groups with the lowest rate of gain also had the highest blood fat level. Bowland and Hironaka (1957) worked only with the Yorkshire, but pointed out the possibility of a breed difference. The Chester White and Poland China breeds did not differ significantly in the present study. The significant association of weight gain and blood fat level within pigs ($r=0.40$) is not in agreement with the non-significant relationship reported by the Canadian workers for Yorkshire pigs.

These data suggest that relatively small differences in age between individual pigs may be of little importance if rate of gain between pigs is held constant. The data also suggest that the phenomena which influence blood fat levels in the individual pig are not operating in the same manner among the treatment groups. The level of protein in the ration and the feeding of an antibiotic have been shown to alter significantly blood fat levels in swine.

Summary

Sixty barrows and gilts of the Chester White and Poland China breeds were allotted randomly to treatment so that one-half of the pigs received protein from a single source and one-half received protein from several sources. Further subdivisions allowed one-half of the pigs to receive antibiotic while one-half did not. One-half of each of these groups received a 12% protein ration and one-half received a 16% protein ration.

Beginning at approximately 4 months of age, blood fat levels were determined at 3-week intervals over a period of 63 days (four samples per pig). Pigs receiving a 12% protein ration averaged 185 mg. % and those receiving a 16% protein ration averaged 166 mg. % ($P<0.01$). The 180 mg. % level of pigs receiving no antibiotics was significantly higher than the 172 mg. % level of those fed chlortetracycline ($P<0.05$). There was no significant difference between the blood fat level of barrows and gilts nor between the two groups receiving protein from different sources. The 177 mg. % level of the Chester White breed did not differ significantly from the 174 mg. % level of the Poland China.

The association within pigs of age and blood fat level was highly significant ($r=0.40$; $P<0.01$) as was the association of weight and blood fat level ($r=0.42$; $P<0.01$). The standard partial regression of these factors, using blood fate level as the dependent variable, was $b'=0.09$ for blood fat on age and $b'=0.36$ for blood fat on weight. There was a highly significant positive association within treatment groups between total pig gain and average blood fat level ($r=0.40$; $P<0.01$). Among the treatment groups the association of gain and blood fat level was negative.

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EFFECT OF ANIMAL FAT AND PROTEIN SUPPLEMENTS ON RANGE BEEF CATTLE

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THE majority of beef cattle in Nevada and a large number in other western states are wintered primarily on native grass hay. Previous work at this station (Bohman and Torell, 1956) has shown that native grass hay is deficient in protein for optimum growth of wintering beef calves. Calves fed protein supplements in addition to grass hay gained more rapidly than control animals.

It is also possible that energy might be a limiting factor in native grass hay for optimum growth of wintering calves. Cereal grains, the usual energy supplements, are not produced in Nevada in large enough amounts to meet the demands of the livestock industry. Fat could be transported into the state more economically per unit of energy than other feed supplements.

This study was conducted to determine the effect of animal fat and protein supplements in the growth and blood constituents of wintering beef calves fed native grass hay.

Experimental Procedure

This experiment was conducted at the Knoll Creek Experimental Range Station in northeastern Elko County during the winters of 1955–56 and 1956–57 and the following summers. Thirty-six weanling steer calves were matched and allotted at random to six experimental treatments each year. The experimental design was a 2×3 factorial.

The winter treatments were two levels of animal fat, 0 and ½ lb. per animal daily, and three protein supplements, none, sun-cured alfalfa meal, and cottonseed meal. Native grass hay and a mineral mixture composed of equal parts of salt and bone meal were fed free-choice. The amount of protein supplied by the alfalfa and cottonseed meal was equalized between treatments. The fat was mixed with the protein supplements, or, when these were not fed, with a pound of ground grass hay and fed once daily. The fat was not stabilized with an antioxidant the first year; the second year butylated hydroxytoluene was used. The chemical composition of the experimental feeds is given in table 1. The calves were maintained in pens in groups of three each during the winter period.

During the summer all cattle grazed together on fenced range without supplements, except for the mineral mixture described previously.

TABLE 1. THE CHEMICAL COMPOSITION OF THE EXPERIMENTAL FEEDS [a]

Feeds	Composition of dry matter				
	Crude protein, %	Ether extract, %	Crude fiber, %	P, %	Carotene, mg./pound
Native grass hay	9.56	2.51	33.3	0.20	11.0
Alfalfa	16.07	2.02	31.1	0.23	20.7
Cottonseed meal	50.94	0.90	11.4	1.46	—

[a] Fat, inedible tallow, had a melting point of 41–43° C. and an Iodine No. of 48.8.

The animals were weighed monthly and blood samples were taken at the same time. Blood was collected by venous puncture into citrated tubes and analyzed for total cells, hemoglobin, phosphorus, vitamin A, carotene and fat. Plasma calcium was also determined initially and at the end of the winter feeding period the first year. The following methods were used for the various chemical determinations: Vitamin A and carotene as described by Kimble (1939); inorganic phosphorus by the method of Fiske and Subba Row (1925); calcium by the method of Clark and Collip (1925) and blood fat by the method of Allen (1938). Total cell count was determined indirectly by diluting 0.075 ml. of whole blood to 25 ml. with normal saline and measuring the turbidity in a Coleman Jr. spectrophotometer at a wave length of 700 mu. The sample was hemolyzed by the addition of a pinch of saponin and the hemoglobin determined colorimetrically as oxyhemoglobin at a wave length of 545 mu.

During the second year the following body measurements were taken initially and at the end of both the winter and summer periods: Height of withers, chest width, heart girth, rump length, and body length. Liver biopsies were taken at the same time by the method of Erwin *et al.* (1956a). Vitamin A and carotene were determined on the liver by the alkali digestion method described by Davis (1939).

All data were subjected to statistical analysis according to methods described by Snedecor (1956) for factorial experiments.

Results and Discussion

The effect of fat and protein supplements on the gains of the calves is given in table 2. The addition of protein from either alfalfa or cottonseed meal increased the rate of gain markedly during the winter period. The following summer on range the relative gains were reversed. Cattle that were retarded during the winter gained more the following summer. Despite the opposing trends in growth response during the winter and summer periods, cattle fed protein supplements in the winter were heavier the next fall. The feeding of protein supplements had little effect upon hay consumption; therefore, total feed consumption in winter was highest for the

TABLE 2. THE EFFECT OF FAT AND PROTEIN SUPPLEMENTS ON GAINS OF GROWING BEEF CATTLE[a] (1955–1957)

Fat supplement	None			0.5 lb daily		
Protein supplement	None	CSM	Alfalfa	None	CSM	Alfalfa
No. of cattle	12	12	12	12	12	12
			Winter Period			
Average no. of days	140	140	140	140	140	140
Initial weight, lb.	388	388	395	385	387	385
Final weight, lb.	489	546	544	469	530	533
Daily gain, lb.	0.72	1.13**	1.06**	0.60	1.11**	1.06**
Daily feed consumed, lb.						
Grass hay	10.4	10.2	9.3	8.8	9.4	8.7
Alfalfa	—	—	3.0	—	—	3.0
Cottonseed meal	—	1.0	—	—	1.0	—
Animal fat	—	—	—	0.5	0.5	0.5
Total	10.4	11.2	12.3	9.3	10.9	12.2
Feed per lb. of gain, lb.						
Grass hay	14.4	9.0	8.8	14.7	8.5	8.2
Alfalfa	—	—	2.8	—	—	2.8
Cottonseed meal	—	0.9	—	—	0.9	—
Animal fat	—	—	—	0.8	0.4	0.5
Total	14.4	9.9	11.6	15.5	9.8	11.5
Daily gain, lb. (summer, 147 days)	1.18	0.94**	1.04**	1.25	1.07**	1.14**
Daily gain, lb. (entire year, 287 days)	0.96	1.03*	1.05*	0.93	1.08*	1.10*

[a] Average values.
*, ** Significantly different from the control rations without supplemental protein at P=.05 and P=.01, respectively.

groups fed protein supplements. These data are in agreement with previous work from this station (Bohman and Torell, 1956).

Animal fat had no effect on the gains of wintering beef calves. During the summer, the cattle fed fat the preceding winter gained more than those not fed fat in the winter. The response to fat appeared to be independent of amount or type of protein. During the first year the difference in rate of gain was statistically different ($P<.01$) although not the second year. Also, fat had no effect on yearly gains. In a previous study (Bohman *et al.*, 1957) fattening beef cattle fed 5% fat gained 28% more than control animals; 10% fat was not as effective in promoting gains as the lower level. In the current study ½ lb. fat daily amounted to approximately 5% of the total ration. In the previous study it was suggested that the level of protein might be an important factor influencing the utilization of fat by ruminants. An excess of protein was fed in that study, while in this experiment only small amounts of protetin were fed. Native grass hay alone did not contain enough protein for optimum growth of wintering cattle and the rations with supplemental protein only provided the extra

amount needed. Since protein-calorie ratios are important for other species (Combs, 1956), it is possible that the amount of protein may not be adequate for the utilization of fat in this study. Erwin *et al* (1956b) have presented data indicating that the type of roughage influences the response to dietary fat. The addition of fat to alfalfa increased the rate of gain while its addition to straw decreased it. In their study the type of roughage and level of protein were confounded. The rate of growth was the same

TABLE 3. THE EFFECT OF PROTEIN SUPPLEMENTS ON BODY MEASUREMENTS (SECOND YEAR)[a]

Measurement and protein supplements	Initial	End of winter period	End of summer period
Heart girth, in.			
None	52.0	54.6	60.4
Alfalfa	52.6	57.3**	62.5**
C.S.M.	52.1	57.2**	61.9**
Chest width, in.			
None	10.9	10.7	13.4
Alfalfa	10.9	11.2*	13.5
C.S.M.	10.8	11.2*	13.2
Body length, in.			
None	41.2	42.6	46.7
Alfalfa	40.7	43.9*	46.5
C.S.M.	41.6	43.8*	47.8
Rump length, in.			
None	14.2	14.9	16.4
Alfalfa	14.5	15.6**	16.9*
C.S.M.	14.4	15.5**	16.8*
Height at withers, in.			
None	37.6	40.2	43.9
Alfalfa	38.5	41.2*	45.3
C.S.M.	38.3	41.2*	45.0

[a] Each figure is the average of 12 animals.
*, ** Statistically significant at P=.05 and P=.01, respectively.

for the animals receiving either alfalfa or cottonseed meal with or without fat in the current study. This also suggests that the amount of protein might be involved rather than the kind of protein for the utilization of fat for growth.

When corn oil or tallow has been fed to ruminants, it has often decreased the rate of gain (Ward *et al.*, 1957; Brethour *et al.*, 1958) and the digestibility of the ration (Ward *et al.*, 1957; Grainger *et al.*, 1957; Pfander and Verma, 1957; Brethour, *et al.*, 1958). The addition of alfalfa, alfalfa ash or calcium overcame this depression in some studies (Ward *et al.*, 1957; Grainger *et al.*, 1957) but not in others (Brethour *et al.*, 1958). The method of administering corn oil to the animal has also been shown to affect digestibility (Pfander and Verma, 1957). It is evident that several factors and conditions influence the utilization of fat by

ruminants and the optimum conditions for the use of this feed material appear to be still unknown.

Other investigators have noted that fat had no effect upon growth but significantly reduced the amount of feed required per unit of gain (Willey *et al.*, 1952; Matsushima and Dowe, 1954). In the current study it was not possible to obtain a statistical evaluation of feed economy since the animals were group-fed, but average data fail to indicate that fat had any effect on feed economy.

The data on weight were confirmed by other body measurements taken the second year. At the end of the winter feeding period, cattle fed protein

TABLE 4. THE EFFECT OF DIETARY FAT ON THE LEVELS OF PLASMA VITAMIN A AND PHOSPHORUS

Plasma constituent	Vitamin A, mcg. %		Phosphorus, mg. %	
Added dietary fat	None	½ lb. daily	None	½ lb. daily
Months:				
December	35.8	34.6	7.35	7.14
January	37.5	40.6*	7.18	6.51
February	40.0	44.1*	7.30	6.87
March	41.1	46.3**	7.98	6.98**
April	40.7	46.3**	8.37	7.88
May	41.4	53.7**	8.07	8.03
June	64.9	72.5	6.92	7.15
July	72.1	75.1	6.60	6.45
August	67.7	65.4	6.77	6.77
September	50.7	49.0	5.55	5.87
October	48.4	46.3	6.64	6.68

*, ** Difference is statistically significant at P=.05 and P=.01, respectively.

supplements had greater body length, rump length, chest width, withers height and heart girth. At the end of the summer grazing period, the protein-supplemented cattle were still longer in the rump and had a larger heart girth (table 3).

All of the body measurements except chest width increased during the winter period for the cattle receiving grass hay only. Kidwell (1955) has shown that chest width is highly related to condition in bovines. Calves would probably be fatter at weaning than later after wintering on grass hay even though growth during the latter period might be evident by other body measurements. Hence, chest width might be expected to be the same at weaning and after a 140-day winter period.

The composition of the blood was influenced by both protein supplements and by fat. Fat temporarily decreased the level of plasma phosphorus (table 4). Bohman and Wade (1958) earlier observed this effect in feed-lot cattle; thus this effect appears to be consistent under two widely different conditions. Even though phosphorus supplements were always available to the cattle, the level of plasma phosphorus was lower

while the animals were on summer range. Phosphorus consumption may have been less during the summer period. Protein had no effect on plasma phosphorus.

Plasma fat was consistently higher when fat was included in the ration but, when fat was removed from the ration, it immediately fell to the level of the non-fat-supplemented animals (fig. 1). At the end of the 140-day winter period the plasma fat of fat-supplemented cattle was more than twice that of the cattle without fat. Each month during that period the value was

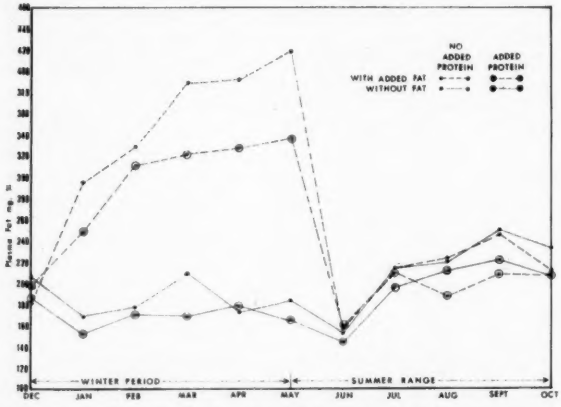

Figure 1. The effect of animal fat and protein supplements on plasma fat.

higher than in the preceding month for the fat-supplemented cattle. A plateau was never reached although the rate of acceleration decreased with time. During the winter period the fat intake was constant.

In contrast, the plasma fat levels of the animals without fat gradually decreased during the winter period, and increased when animals were on summer range. Bohman and Wade (1958), Willey *et al.* (1952), and Bender and Maynard (1932) also found that dietary fat markedly increased the level of plasma fat. In a previous experiment with fattening steers, Bohman and Wade (1958) observed that the plasma level of fat increased with time regardless of whether cattle were fed extra fat or not; it appeared that plasma fat might be related to fat deposition but correlations of terminal plasma fat with carcass data did not reveal this to be true.

Since alfalfa and cottonseed meal gave similar responses, the data involving these supplements have been averaged for discussion of the effect of protein on blood constituents. Protein decreased the level of plasma fat when fat was fed; without extra dietary fat, protein had no effect on plasma fat (fig. 1). This interaction was statistically significant.

The intake of carotene by the groups with and without the fat supplement was approximately equal. The fat supplement markedly increased the levels of plasma carotene (fig. 2), and these levels paralleled the levels of plasma fat during the winter feeding period. The effect of fat on plasma vitamin A was similar (table 4). The highest plasma levels of carotene, vitamin A and fat occurred at the end of the winter period when the animals were supplemented with fat. The level of these constituents in the blood of non-fat-supplemented cattle was relatively constant

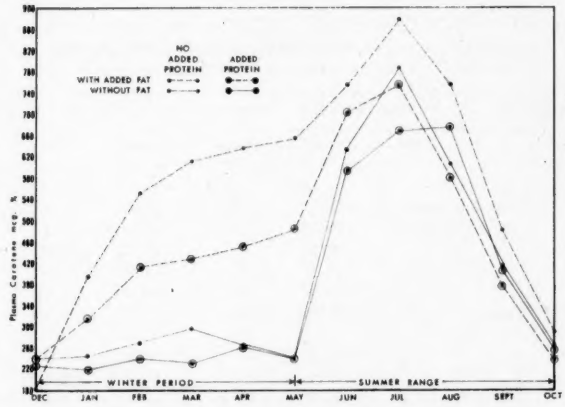

Figure 2. The effect of animal fat and protein supplements on plasma carotene.

during the winter period. These vitamin A and carotene plasma levels could reflect either greater absorption from the digestive tract with extra dietary fat or a decreased utilization by the animal with the resultant accumulation in the blood. Willey *et al.* (1952) have obtained similar results and interpreted the increased levels of plasma vitamin A and carotene as meaning greater absorption and utilization of dietary carotene. The conclusions were drawn despite the fact that the level of carotene in the body fat was less with the high fat ration than the conventional ration. Liver storage of carotene or vitamin A was not determined. The results in the current study were comparable each year despite the fact that an antioxidant was used the second year but not the first. Previous work (Bohman and Wade, 1958) has shown that supplementary fat either maintained or decreased the level of plamsa carotene and vitamin A. It is likely that the fat was rancid under the conditions of that study. It was suggested that carotene was probably destroyed by oxidative rancidity within the rumen. The dietary fat was not rancid in this study.

Protein decreased the plasma levels of carotene (fig. 2). Although the cattle supplemented with alfalfa meal had a higher carotene intake than those supplemented with cottonseed meal during the winter period, this was not reflected in the levels of plasma carotene and vitamin A. Most of the dietary carotene for all animals was supplied by the native grass hay. Since the amount of carotene supplied by the grass hay greatly exceeded (3–4 times) the requirements of the cattle (Morrison, 1956) and the protein supplied by either alfalfa or cottonseed meal influenced the level of plasma carotene, the effect of additional dietary carotene on

TABLE 5. THE EFFECT OF DIETARY PROTEIN ON THE LEVEL OF PLASMA VITAMIN A, HEMOGLOBIN AND TOTAL CELLS

Blood constituent	Vitamin A, mcg. %		Hemoglobin, gm. %		Total cells, millions/mm.^{3}	
Supplement	None	Protein	None	Protein	None	Protein
Months:						
December (initial)	37.8	34.0	15.0	14.8	7.49	7.43
January	40.7	38.2*	13.4	13.6	6.51	6.67
February	44.7	40.8*	14.1	15.0**	6.61	7.26*
March	45.4	41.6*	14.7	15.3*	6.64	7.41**
April	45.3	42.6*	14.9	15.4*	7.47	7.90**
May (end of winter period)	50.3	46.2*	14.5	15.1*	7.30	7.75**
June	71.2	67.5	14.2	15.0*	7.25	7.72
July	80.0	70.4	14.3	13.8	6.97	6.78
August	67.9	63.5	14.8	13.9	7.46	6.90
September	49.0	50.2	15.9	15.3	7.85	7.66
October (final)	49.4	46.3	15.3	15.5	7.77	7.69

*, ** Significant at P=.05 and P=.01, respectively.

plasma levels was probably masked under these conditions. Protein decreased the levels of plasma vitamin A (table 5).

Liver biopsies were taken the second year to determine the effect of supplementary fat and protein, and consequent blood levels of vitamin A and carotene, on liver storage of carotene and vitamin A. The level of liver vitamin A at the end of the winter feeding period was almost the same as the initial level for cattle receiving ½ lb. fat daily. In contrast, the level of vitamin A in the liver of the other animals increased approximately 24% (table 6). When cattle are receiving more carotene than they require for their immediate nutritional needs, it would appear that the utilization of dietary carotene might be measured by its subsequent storage in the liver as vitamin A. Since the level of plasma carotene was high and the level of liver vitamin A was low, it would appear that the dietary fat was depressing the utilization of carotene or vitamin A. At the end of the summer grazing periods, the vitamin A store was approximately the same although favoring the animals that had not received fat the pre-

ceding winter. The storage of carotene was not affected by dietary fat. In contrast Erwin *et al.* (1956c) found that dietary fat significantly increased carotene storage but had no effect on the storage of vitamin A.

Protein supplementation decreased the storage of vitamin A and carotene in the liver (table 6). The mechanism whereby protein influences liver stores of vitamin A and carotene is not readily apparent.

None of the dietary treatments had any effect on plasma calcium when measured. Animals fed protein supplements maintained their levels of hemoglobin and total cells at a pre-experimental level during the winter period while the levels of these blood constituents gradually decreased

TABLE 6. THE EFFECT OF DIETARY FAT AND PROTEIN ON LIVER VITAMIN A AND CAROTENE

	Fat		Protein	
Supplement level	None	½ lb. daily	None	1 lb. CSM or 3 lb. alfalfa
	Vitamin A, micrograms/gm.			
Initial (December)	41.5	36.2	39.9	38.3
End of winter period (May)	51.3	35.8**	59.4	35.7**
Final (October)	54.0	48.8	55.8	49.2
	Carotene, micrograms/gm.			
Initial (December)	3.5	3.8	4.4	3.2
End of winter period (May)	7.5	8.0	11.0	6.1**
Final (October)	6.0	5.4	6.1	5.5

** Statistically significant at P=.01.

when no supplemental protein was fed (table 5). This effect which might be expected is in agreement with work of Bedrak *et al.* (1956, 1957). One month after the cattle were on the summer range, the hemoglobin was still not equal between the two groups. The levels of the hemoglobin and total cells were not influenced by dietary fat.

Summary

Thirty-six weanling steer claves were allotted to treatments in a 2 x 3 factorial designed experiment each year for 2 years. The winter treatments were two levels of fat and three protein supplements. Following the winter period all cattle ranged together until fall.

Protein supplements increased the rate of gain during the winter and for the entire year but the animals without a winter protein supplement gained faster during the summer. Supplemental fat had no significant effect on rate of gain. Other body measurements supported these weight changes.

Dietary fat increased the level of plasma fat, vitamin A and carotene;

had no effect on total cells, hemoglobin or liver storage of carotene; temporarily decreased the level of plasma phosphorus; and, decreased the storage of vitamin A during the winter period. During this same period supplementary protein decreased the level of plasma fat and plasma carotene when extra fat was fed; when extra fat was not fed, it had no effect on these constituents; it also decreased plasma vitamin A. Total cells and hemoglobin levels were maintained at their pre-experimental level when extra protein was fed while the level of these constituents decreased in the non-protein-supplemental animals. When extra protein was fed, less vitamin A and carotene was stored in the liver. All blood values became equalized during the summer period.

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THE RELATION OF PRE-NATAL AND PRE-WEANING TREATMENT TO THE EFFECT OF ARSANILIC ACID ON SELENIUM POISONING IN WEANLING PIGS [1]

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SWINE raised in seleniferous areas ingest varying amounts of selenium at most all times. The previous nutritional treatment might be expected to modify the degree to which a weanling pig is affected by selenized rations. In our previous work (Wahlstrom *et al.*, 1955, 1956) in which experimental animals had not been fed selenized rations prior to the experimental period, 10 ppm. of selenium caused toxicity in weanling pigs and arsanilic acid gave good protection against it. More recently Wahlstrom and Olson (1958) reported lighter birth weights and increased mortality in pigs farrowed from sows receiving selenized rations, and that arsanilic acid in the sow ration did not protect against these effects.

The purpose of this study was to determine the effect of previous nutritional treatment on the value of arsanilic acid as a preventive of selenium poisoning in pigs.

Experimental Procedure

This study consisted of two trials with weanling pigs in concrete drylot. Ninety purebred Duroc pigs were used in the first trial. Thirty of these pigs were weaned from sows fed selenized rations during growth, gestation and lactation and 30 of them were from sows fed rations containing arsanilic acid in addition to selenium during those periods. The other 30 pigs were from sows fed non-selenized rations. Each group of 30 pigs was divided into three lots each of 10 pigs.

In the second trial 54 crossbred pigs were used. These pigs were farrowed by the same sows as the pigs in trial 1 but were sired by a Poland China boar. Eighteen pigs from each of the three groups of sows were divided into three lots each of six pigs. The experimental plan describing the various treatments is given with the results in table 1.

The basal ration was composed of 84 parts of ground yellow corn, 10 parts of 44% protein solvent soybean meal, 5 parts of 60% protein tankage, 0.5 part of steamed bone meal and 0.5 part of trace mineralized

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salt. A vitamin premix contributed 1 mg. riboflavin, 2 mg. calcium pantothenate, 4.5 mg. niacin, 5 mg. choline and 4.5 mcg. vitamin B_{12} per lb. of mixed ration. Selenium when fed was added as sodium selenite to furnish 10 ppm. of selenium to the total ration. Arsanilic acid when fed was added at a level of 0.01% of the ration.

In both trials the growth data were treated statistically by analysis of variance as outlined by Snedecor (1946).

TABLE 1. EFFECT OF ARSANILIC ACID IN COUNTERACTING SELENIUM POISONING IN PIGS WITH DIFFERENT PRE-WEANING TREATMENTS (TRIAL 1)[a]

Lot no.	Additions to rations		No. of pigs showing toxicity symptoms	Av. initial wt., lb.	Av. final wt., lb.	Av. daily gain, lb.[b]	Feed/cwt. gain, lb.
	Dams	Pigs					
1	None	None	0	31.6	97.4	1.17	250
2	None	Se	10	31.6	43.0	0.24	574
3	None	Se+AA	2	31.6	77.5	0.82	244
4	Se[c]	None	0	24.2	68.1	0.82	280
5	Se	Se	2	25.5	53.8	0.53	346
6	Se	Se+AA	0	24.9	59.8	0.66	278
7	Se+AA[d]	None	0	27.2	72.4	0.82	270
8	Se+AA	Se	5	27.3	48.0	0.38	402
9	Se+AA	Se+AA	2	27.5	63.3	0.65	347

[a] Ten pigs per group except lots 5 and 6. Two pigs died in Lot 5 and one pig in Lot 6. Data are for pigs that finished test.
[b] L.S.D. at $P<0.05=0.25$; and at $P<0.01=0.33$.
[c] Se=10 ppm. selenium.
[d] AA=0.01% arsanilic acid.

Results and Discussion

The results of the first trial with selenium and arsanilic acid supplementation of the basal rations are shown in table 1. When 10 ppm. of selenium was added to the basal ration (Lot 2) a marked reduction in growth rate occurred. These pigs had not had access to selenized rations previous to this trial. All of the pigs in Lot 2, showed loss of hair and cracking of the hoofs. Only two of the pigs in Lot 3, which were fed rations containing arsanilic acid and selenium, showed these symptoms and these pigs were only mildly affected. Although arsanilic acid did not completely counteract the effects of selenium in reducing growth rate, it did cause a marked improvement. The severity and number of visible selenium toxicity symptoms were reduced.

A comparison of the pigs in Lots 5 and 6 with those in Lot 4 also shows a reduction in growth due to selenium. The dams of the pigs in these three lots had all been fed selenium during growth, pregnancy and the subsequent suckling period. The effect of selenium on the pigs in Lot 5 did not appear to be as severe as on those in Lot 2. This is indicated by both rate of gain and visible toxicity symptoms. Two pigs in Lot 5 died early in the trial and did not exhibit selenium toxicity symptoms at the

time of death. The slower rate of gain of the pigs in Lot 4 as compared to Lot 1, both of which received the non-selenized basal ration, was due likely to the effects of selenium previous to the time of this trial. A comparison of the initial weights of the pigs also indicates the effects of the previous selenium treatments, as all lots of pigs were started on experiment at approximately the same age.

The pigs in Lots 7, 8 and 9 were weaned from sows that had been fed rations containing both selenium and arsanilic acid. The rate of gain of the pigs in Lot 7, fed the basal ration, was identical to that of Lot 4 and significantly less than that of Lot 1. Feeding the selenized ration to Lot 8 resulted in a slow rate of gain (0.38 lb. per day) and five of the pigs

TABLE 2. THE EFFECT OF ARSANILIC ACID IN COUNTERACTING SELENIUM POISONING IN PIGS WITH DIFFERENT PRE-WEANING TREATMENTS (TRIAL 2)[a]

Lot no.	Additions to rations		No. of pigs showing toxicity symptoms	Av. initial wt., lb.	Av. final wt., lb.	Av. daily gain, lb.[b]	Feed/cwt. gain, lb.
	Dams	Pigs					
1	None	None	0	32.7	109.5	1.37	282
2	None	Se	2	32.7	82.5	0.89	305
3	None	Se+AA	0	32.7	107.5	1.34	275
4	Se[c]	None	0	28.8	73.4	0.80	279
5	Se	Se	1	30.2	87.0	1.01	298
6	Se	Se+AA	0	28.6	78.0	0.88	289
7	Se+AA[d]	None	0	30.2	85.8	0.99	267
8	Se+AA	Se	2	30.2	76.5	0.83	324
9	Se+AA	Se+AA	0	30.2	87.5	1.02	283

[a] Six pigs per group except Lots 4, 5 and 6. One pig died in each of Lots 4 and 6 and two pigs in Lot 5. Data are for pigs that finished the test.
[b] L.S.D. at $P<0.05=0.26$; and at $P<0.01=0.34$.
[c] Se=10 ppm. selenium.
[d] AA=0.01% arsanilic acid.

showed selenium toxicity symptoms. Adding arsanilic acid to the ration increased the rate of gain to 0.65 lb. per day and only two of the 10 pigs showed symptoms of selenium poisoning. These symptoms were also less severe than those of the pigs in Lot 8.

There are at least two possible explanations for the pigs in Lot 2 showing the most severe toxicity symptoms followed in order by Lots 8 and 5. It is possible that the greater death loss of the pigs at birth and during lactation, from sows fed selenium, may have eliminated some of the more susceptible individuals in these lots (Wahlstrom and Olson, 1958). A great individual variation in susceptibility to selenium has been noted in our previous work. It may also be possible that a tolerance for selenium is built up in those animals that have been exposed to it over a long period of time.

The addition of arsanilic acid to the selenized rations resulted in increased growth rate, increased feed consumption, improved feed ef-

ficiency and a reduction in visible selenium poisoning symtoms. This was observed in all three lots (Lots 3, 6 and 9) compared to the corresponding lots (Lots 2, 5 and 8) fed the selenized ration without arsanilic acid.

The results of trial 2 are summarized in table 2. Toxicity symptoms were not so severe as in trial 1. However, the effects of selenium and of previous selenium treatment were similar to those observed in trial 1. The crossbred pigs in trial 2 may have been less susceptible to selenium poisoning than the Duroc pigs in trial 1 as breed differences in susceptibility to selenium poisoning have been noted previously (Wahlstrom *et al.*, 1955).

Of the pigs fed the basal ration, those from sows not fed selenium (Lot 1) gained significantly faster than those from sows fed selenium (Lots 4 and 7). Ten ppm. of selenium caused a significant reduction in growth rate of pigs from sows not fed selenium (Lot 2 vs. Lot 1) an increase in growth rate of those from sows fed selenium (Lots 5 vs. Lot 4) and a slight but not significant reduction in growth rate of those from sows fed selenium plus arsanilic acid (Lot 8 vs. Lot 7). Perhaps part of this difference in rate of gain between Lots 4 and 5 can be attributed to the death of the smaller pigs in Lot 5 and the development of resistance to selenium by those that survived.

Feeding the pigs rations which contained selenium and arsanilic acid, Lots 3, 6 and 9, resulted in gains similar to those made by the pigs fed the basal rations, Lots 1, 4, and 7, respectively. The apparent protection from selenium poisoning by arsanilic acid in this trial is consistent with our previous work in which selenium toxicity had not been severe (Wahlstrom *et al.*, 1955, 1956).

Summary

A total of 144 weanling pigs farrowed by sows fed control, selenium and selenium plus arsanilic acid rations were used to determine performance of weanling pigs subjected to these same ration treatments.

Feeding a non-selenized basal ration to pigs from similarly fed dams resulted in a faster rate of gain than was obtained when this ration was fed to pigs weaned from sows fed rations containing added selenium or selenium and arsanilic acid.

Ten ppm. of selenite selenium in the ration of weanling pigs caused a greater reduction in rate of gain and more selenium toxicity symptoms in pigs which had not had access to selenized rations previous to weaning than in pigs whose dams had received selenium during growth, gestation and lactation. Pigs from sows that had been fed selenized rations over a long period of time appeared to be more resistant to selenium toxicity.

The addition of 0.01% of arsanilic acid to the selenized ration resulted in increased growth rate, increased feed consumption, improved feed efficiency and a reduction in visible selenium poisoning symptoms. The

greatest benefit from arsanilic acid was noted in the pigs from dams fed non-selenized rations and the least response in those from dams fed selenized rations.

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SIGNIFICANT RELATIONSHIPS IN PORK CARCASS EVALUATION [1, 2]

II. Measurements and Cuts of Fat as Criteria for Live Hog Value

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IN recent years the price differential between fat and lean cuts has emphasized the need for reliable methods of evaluating the pork carcass. The economic importance of accurately estimating the yield of fat and lean in a live hog or pork carcass has been brought to the attention of the producer, processor and marketing agencies in an attempt to satisfy the needs of the consumer. The relationship of live hog and carcass measurements to the yield of lean cuts has been reported by Zobrisky *et al.* (1959a).

Warner *et al.* (1934) reported a correlation of 0.91 between the percent fat cuts and the fat content of the edible meat in the pork carcass. The yield of fat can be more easily and accurately determined than the yield of lean in the live hog (Hazel and Kline, 1952; Zobrisky, 1954), and in the carcass (Wiley *et al.*, 1951). Furthermore, the yield of fat is as valuable as the yield of the lean for estimating carcass value. The purpose of this study was to determine the relationship of live hog and carcass measurements to the yield of carcass trim fat.

Materials and Methods

The 207 hogs and carcasses included in this study consisted of 122 Landrace-Polands, 76 Hampshires and 9 Durocs. Live hog backfat probe measurements were taken the day before slaughtering. Hogs attaining a weight of 205 to 215 lb. were weighed, fasted 24 hours with access to water, re-weighed, then slaughtered. All hogs were dressed with the head off, leaf fat attached and hams unfaced. Measurements were taken on chilled half-carcasses as the carcasses were processed. Backfat thickness measurements were taken over the first rib, the last rib and the last lumbar vertebra. Carcass length was measured from the anterior edge of the aitch bone to the anterior edge of the first rib. Ham fat thickness is the thickness of the subcutaneous fat opposite the exposed ilium of the ham end. Carcass width is the total of two measurements, one of each side, taken with a caliper from the split surface of the seventh thoracic vertebra to the outside surface of the carcass.

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The carcasses were broken down into wholesale cuts and each trimmed as outlined in the Proceedings of the Fifth Annual Reciprocal Meat Conference (1952). All yields were based on the chilled carcass weight and the empty liveweight. The empty liveweight was determined by adjusting the shrunk liveweight with respect to digestive tract "fill

TABLE 1. CORRELATIONS BETWEEN INDEPENDENT VARIABLES AND THE YIELD OF FAT AND FOUR LEAN CUTS

Independent variables	Number in in sample	Correlation coefficients [c]	
		Yield of fat [a]	Yield of four lean cuts [b]
Av. of 3 live hog probes, mm.	108	0.61	—.36
Ham probe, mm.	108	.60	—.35
Hip probe, mm.	108	.51	—.43
Shoulder probe, mm.	108	.40	—.21
Ham fat trim, lb.	108	.73	—.46
Av. of 3 carcass backfat thickness, mm.	207	.67	
Last thoracic backfat thickness, mm.	207	.42	
Carcass ham fat thickness, mm.	207	.49	
Backfat, % liveweight	108	.83	
Leaf fat, % liveweight	108	.40	
Carcass trim fat, % liveweight	108	.85	
Dressing, %	187	.26	
Cooler shrink, %	207	—.23	

[a] Total carcass trim fat+leaf fat.
[b] Ham, loin, Boston butt and picnic.
[c] All correlation coefficients are highly significant ($P<.01$) except $r=-.21$ which is significant ($P<.05$).

weight". "Fill weight" was the difference between the full and empty digestive tract weight. Additional methods of procedure were previously reported by Zobrisky *et al.* 1959).

Results and Discussions

Table 1 shows that the average of the three live-hog backfat probe measurements was significantly correlated ($r=0.61$) with the yield of fat (total carcass trim fat and leaf fat). The ham probe was the most highly correlated of individual probes with the yield of fat ($r=0.60$) followed by the hip probe ($r=0.51$) and shoulder probe ($r=0.40$). Hazel and Kline (1953) reported correlations of the same general magnitude between probe measurements taken at sites approximating the ham and hip probe; however, the correlation between the shoulder probe and the yield of fat was approximately twice as large as herein reported, 0.76 vs. 0.40. The shoulder probe in the present study was taken 1.5 in. off the mid-line of the back at approximately the 5th–6th thoracic vertebra over the trapezius muscle, which extends to the 10th thoracic vertebra,

whereas, Hazel and Kline (1953) probed, "Behind shoulder over longissimus dorsi—"muscle.

Recently Holland and Hazel (1958) reported correlations between the three individual probe measurements and the yield of fat which indicate that the correlation between the shoulder probe and the yield of fat is not as great as previously reported by Hazel and Kline (1953). Hetzer *et al.* (1956) reported correlations of 0.36, 0.41 and 0.50 between the shoulder, mid-back and mid-loin probes, respectively, and the yield of fat (table 2).

TABLE 2. CORRELATIONS BETWEEN BACKFAT PROBE MEASUREMENTS AND THE YIELD OF FAT

	Station and dates			
	Missouri	Iowa		U.S.D.A.
Probe site	1958	1953	1958	1956
Behind shoulder (shoulder probe)	0.40[a]	0.76	0.60	0.36
Mid-back (hip probe)	.51	.53	.72	.41
Mid-loin (ham probe)	.60	.66	.71	.50
Av. of probes	.61[b]	.79[c]	.78[b]	.54[b]

[a] All highly significant ($P<.01$).
[b] Av. of three backfat probes.
[c] Av. of four backfat probes.

The differences due to breed, worker, probe site and probe depth (whether the measurement is obtained consistently over the trapezius or longissimus dorsi muscle behind shoulder) possibly account for the difference in results reported by various investigators.

The correlations in the first column of table 2 were tested for significance of differences according to Mills (1938). The ham probe "r" was significantly larger ($P<.01$) than the shoulder probe "r". There were no statistically significant differences between the other individual probe-fat correlations in the present study.

The three live hog probe measurements were also used as independent variables to determine their combined relationship to the yield of fat. The coefficient of multiple correlation was 0.63. The calculated regression equation for estimating the yield of fat from the three probes was:

Percent carcass trim fat of the live weight$=7.27+0.020\times$shoulder probe (mm.)$+0.088\times$hip probe (mm.)$+0.205\times$ham probe (mm.). The magnitude of the partial regression coefficients in the equation parallel the relative magnitude of the correlations between each of the three probes and the yield of fat.

The correlations given in table 1 between the probes and the yield of fat were of greater magnitude than the correlations between the probes and the yield of four lean cuts. The probes are measurements of sub-

cutaneous fat thickness. Therefore, the correlations between probes and the yield of the tissue of which they are measurements logically should be greater than between the probes and a measurement of fat, lean and bone, i.e., the yield of four lean cuts.

The average of the three carcass backfat measurements was highly correlated with the yield of fat (r=0.67). The average of the three live hog backfat measurements are equal in value (r=0.61) for estimating the yield of fat. The advantages of one method over the other depends on when the measurements are obtained, on the live hog or carcass, during the evaluation procedure. No significant difference was found between these two correlations.

The relationships of the yield of fat with carcass backfat, width and length measurements were studied. The correlations between carcass width and length with the yield of fat were not significant. The interrelationships indicated that carcass width increased as backfat thickness increased, (r+0.23), whereas backfat thickness and carcass width decreased as the length of the carcass increased (r=—0.12 and —0.31, respectively). The yield of fat increased with an increase in backfat thickness when the influence of carcass width and length were accounted for in partial correlation analysis (0.70). The yield of fat also increased with an increase in carcass length when carcass width and backfat thickness were held constant (0.28). There was, however, no significant relationship between the yield of fat and carcass width when backfat thickness and carcass length were held constant. These gross and partial correlations indicate that within the range of live weights studied (205–215 lb.) the yield of fat was associated with the thickness of backfat. Length and width of carcass appeared to have little relationship to the yield of fat.

The thickness of ham fat and the backfat thickness at the last thoracic vertebra were also correlated with the yield of fat (r=0.49 and 0.42, respectively). The correlations between measurements and yield of fat (table 1) suggest that measurements obtained from the last rib to the 2nd–3rd sacral veterbra were most indicative of the yield of fat. Measurements taken within the region include the ham fat thickness, last thoracic backfat thickness and the live hog hip and ham probe. The live hog ham probe measurements obtained at approximately the 4th–5th lumbar vertebra appear to provide the best single fat-thickness index.

The fat trimmed from the skinned ham was highly associated with the yield of fat (r=0.73). A strong relationship would be expected between these two variables. As hogs deposit fat the plumpness of the ham increases (Hankins, 1940).

The percent leaf fat, carcass trim fat and backfat were each significantly correlated with yield of fat (r=0.40, 0.85 and 0.83, respectively). The latter two relationships could be very useful when backfat measurements are not obtained.

Carcass cooler shrinkage decreased ($r=-0.23$) while carcass dressing percent and the yield of fat increased ($r=0.26$). These correlations indicate that carcass cooler shrink and dressing percent are influenced by the yield of fat. However, the magnitudes of the correlations indicate that other factors not considered in this study may have an important influence on these two variables.

The results of this study indicate that the average of the three live hog backfat probes and the average of the three carcass backfat measurements are equal in value as an index for the yield of fat.

The gross correlations of the yield of fat with length and width of carcass with cooler shrinkage and dressing percent are small and of little practical significance.

Summary

Backfat thickness measurements were the best indicators of yield of fat. As a single measurement, the ham probe was superior to the hip probe or shoulder probe as an indicator of fatness. Partial correlation analysis indicated that carcass length was interrelated with carcass width and backfat thickness. Therefore, length has a minor influence on the yield of fat.

Dressing percent and cooler shrink were associated with carcass finish. Although the correlations were highly significant they were of small magnitude.

A reasonably accurate estimate of the yield of fat can be determined from the live hog backfat probes or carcass backfat measurements. Yield of fat can be more accurately measured in the live hog or carcass than the yield of the four lean cuts. This is possibly due to the well-defined regions present on the carcass and live animal for taking measurements associated with fatness. Most measurements of fatness measure the subcutaneous fat alone, whereas, most measurements used to evaluate the lean are, in part, measures of fat, lean and bone or some combination of these three components.

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SIGNIFICANT RELATIONSHIPS IN PORK CARCASS EVALUATION

III. Dressing Percent as a Criterion for Live Hog Value [1, 2]

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DRESSING percent and the yield of wholesale cuts are closely associated in hogs of similar finish and weight. Dressing percent is, therefore, an important measure of the hog's value. Hankins (1940) and Warner *et al.* (1934) indicated that an increase in fatness is accompanied by an increase in weight and yield of the dressed carcass. According to Hammond and Murray (1937) dressing percent is influenced more by the weight of the hog than by breed or type.

This study was designed to determine the relationship of dressing percent to carcass measurements and the yield of component cuts. The correlations between carcass merit scores and measurements of the live hog and carcass will be reported in a subsequent paper.

Materials and Methods

A total of 201 hogs of approximately 200 lb. liveweight were included in this study. They consisted of 116 Landrace-Poland crosses, 76 Hampshires and 9 Durocs. Sixty-seven of the hogs were slaughtered in the autumn of 1952 and 134 in the spring of 1953. Pre-slaughter treatment, method of processing and the method of determining yields have been reported previously by Zobrisky *et al.* (1959a, 1959b).

The carcass measurements analyzed in relation to dressing percent were: Carcass length, measured from anterior edge of aitch bone to the anterior edge of first rib; carcass depth, a measurement of the total depth of carcass, including skin, across the first thoracic vertebra; and carcass width, the total of two measurements, one of each side, taken with a caliper from the split surface of the seventh thoracic vetebra to the outside surface of the carcass. Fat is the total yield of back fat, leaf fat, clear plate and trimmings. Lean is the total yield of hams, loins, shoulders and lean trimmings. Miscellaneous cuts included the total yield of feet, tail, kidneys, spare ribs, neckbones and jowls.

Dressing percent was calculated from the empty liveweight and the chilled carcass weight. The empty liveweight was determined by subtracting the weight of the digestive tract contents (fill) from the 24-hour fasted weight (shrunk, live weight).

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[2] This research was in cooperation with the Regional Swine Breeding Laboratory, AHRD., ARS., U. S. Department of Agriculture.
[3] Professor Emeritus.

Results and Discussion

Dressing percent is influenced primarily by the weight of the digestive tract, fill, thoracic organs and head. Autumn slaughtered, unfasted, hogs (Zobrisky, 1953) had an average empty digestive tract weight of 17.03 lb. and average fill of 10.21 lb. In the present study, autumn-slaughtered hogs of similar weight and breeding fasted 24 hr. before slaughter with access to water had an average empty tract weight of 14.1 lb., and an average fill of 3.2 lb. The difference in fill affected the carcass yields of

TABLE 1. RELIABILITY OF VARIABLES STUDIED

Variable	Number in samples	Mean	Range		Standard error of mean
			High	Low	
Empty live weight, lb.	189	198.9	221.5	180.0	7.7
Dressing, %	189	76.6	87.2	67.5	2.3
Carcass length, mm.	201	736.8	786.0	688.0	23.2
Carcass width, mm.	201	264.8	286.0	231.0	13.2
Carcass depth, mm.	201	340.0	372.0	300.0	13.9
Total fat, %	201	17.6	31.4	10.0	2.8
Total lean, %	189	39.6	47.4	32.6	2.8
Miscellaneous cuts, %	189	8.6	10.0	7.0	0.6

[a] Total yield of feet, tail, kidney, spare ribs, neckbones and jowls.

these autumn-slaughtered hogs from 2 to 5%. The intestinal fill of fasted spring-slaughtered hogs averaged 3.1 lb. and the empty digestive tract averaged 10.8 lb. The fasted spring-slaughtered hogs dressed 2 to 3 percentage points higher than the fasted autumn-slaughtered hogs. This difference is partially accounted for by the difference in fill and in the digestive tract weight. The autumn- and spring-slaughtered hogs received the same rations although the former were on pasture.

The influence of fill on dressing percent as discussed above was accounted for in this study by employing the empty live weight and chilled carcass weight in determining dressing percent. The mean, the range and standard error of the variables included in this study are presented in table I.

Carcass depth, width and length were correlated with dressing percent as follows: Carcass depth, $r=0.18$; carcass width, $r=0.45$; and carcass length, $r=-.09$ (table 2). These correlations indicate that dressing percent, carcass depth and width tend to be directly associated. However, carcass length was not significantly correlated with dressing percent. Carcass depth and carcass width were directly correlated, $r=0.33$. Carcass length was negatively correlated with carcass depth and width, $r=-.31$, $r=-.29$, respectively.

The multiple correlation coefficient between dressing percent and carcass depth and width was 0.47. The regression equation for estimating dressing percent was:

(a) Dressing percent=54.68+0.006×carcass depth (mm.)+0.076× carcass width (mm.).

While it is generally accepted that dressing percent is influenced by the fat, lean and bone, the question still remains as to which of the three components has the greatest influence. Numerous investigators have reported that fat hogs have a higher dressing percent than lean hogs. Hankins *et al.* (1953), however, suggested that the percent of preferred cuts (hams, loins, shoulders and bellies) has a greater effect on dressing percent than the yield of fat (backfat, leaf fat, clear plate and fat trimmings). They

TABLE 2. CORRELATION BETWEEN DRESSING PERCENTAGE AND INDEPENDENT VARIABLES [a]

r_{12}= 0.26**	$r_{12.8}$ = 0.66**	r_{18}= 0.18**
r_{13}= .36**	$r_{13.2}$ = .68**	r_{16}= .45**
r_{14}= .35**	$r_{14.2}$ = .50**	r_{17}=−.09
r_{23}=−.62**	$r_{12.34}$= .70**	r_{56}= .33**
r_{24}=−.36**	$r_{13.24}$= .63**	r_{57}= .29**
r_{34}= .47**	$r_{14.23}$= .38**	r_{67}=−.31**

[a] N=189.
** Probability of chance occurrence <.01.

1. Dressing percent
2. Yield of fat
3. Yield of lean
4. Yield of miscellaneous cuts
5. Carcass depth
6. Carcass width
7. Carcass length

reported a coefficient of multiple correlation of 0.91. Their regression equation was:

(b) Dressing percent=33.16+0.786×percent preferred cuts+0.606 ×percent fat cuts.

The calculated regression equation for similar variables from the present study was:

(c) Dressing percent=35.78+0.722×percent lean cuts+0.707× percent fat.

The coefficient of multiple correlation was 0.72. The similarity of the numerical values in these two equations (b and c) is readily evident. These equations indicate that the percent of lean cuts contributed more to dressing percent than the percent of fat when considered on the basis of per unit yield or total contribution to the end product.

Miscellaneous cuts, i.e., the total yield of feet, tail, kidneys, spare ribs, neckbones and jowls were not considered in equations (b) and (c). Nevertheless, the miscellaneous cuts affect the magnitude of the partial regression coefficients of the percent lean and fat. Influence of the miscellaneous cuts is in relation to the magnitude of the inter-correlations of the variables considered, dressing percent, fat, lean and the miscellaneous cuts, which are given in table 2 [4]. In regard to dressing percent, percent lean and the

[4] Belly was not considered in the relationship of dressing percent and the other variables discussed herein.

miscellaneous cuts were positively correlated and therefore complemented one another. The percent fat was negatively correlated with the percent lean and the miscellaneous cuts. Therefore, percent fat contributed, in relation to dressing percent, an opposing influence when considered with lean and the miscellaneous cuts. This can be illustrated by studying correlations presented in Table 2. The correlation between dressing percent and percent lean, $r_{13}=0.36$, increased to $r_{13.2}=0.68$ when the opposing influence of the percent fat was held constant by partial correlation analysis. When the complementary influence between percent lean and the miscellaneous cuts, $r_{34}=0.47$, was also held constant the correlation between dressing percent and percent lean ($r_{13.24}$) decreased to 0.63. Considering the coefficients between dressing percent and the miscellaneous cuts in the same manner, a similar increase and decline in "r" was noted. The gross correlation coefficient between dressing percent and percent fat was 0.26. The partial correlation coefficient between dressing percent and percent of fat ($r_{12.3}$) increased to 0.66 when the negative influence between fat and lean, $r_{23}=-.62$, was accounted for. When the negative influence between fat and lean (r_{23}) and fat and the miscellaneous cuts ($r_{24}=-.36$) was accounted for, the partial correlation coefficient between dressing percent and percent fat ($r_{12.34}$) increased to 0.70. These coefficients indicate that fat, lean and the miscellaneous cuts have a marked effect on dressing percent.

The calculated regression equation for estimating dressing percent from the percent of fat, lean and the miscellaneous cuts was:

(d) Dressing percent$=23.66+0.737\times$percent fat cuts$+0.615\times$percent lean cuts$+1.845\times$percent miscellaneous cuts.

The coefficient of multiple correlation was 0.76.

The partial regression coefficients in equation (d) indicate that per unit yield the miscellaneous cuts had more influence than fat and fat had slightly more influence than lean on the dressing percent. However, the yield of lean contributed more to dressing percent than the yield of miscellaneous cuts or fat by virtue of a greater percentage yield as indicated in table 1.

These results indicate that many factors have an influence upon the dressing percent of hogs. The weight of the internal organs, the amount of intestinal fill, muscular development, finish and conformation all have an influence on the yield of carcass from the live hog.

Hogs reared with access to forage tend to have heavier intestines than those reared in dry lots. This could be confounded with a seasonal effect on dressing percent. The weight of intestinal fill depends on the managerial practices followed within the last 24 to 36 hr. prior to slaughter. The greater the muscular development and finish, the greater the dressing percent when intestinal weight and fill are constant. Muscle, fat and bone influence dressing percent. The component present in the largest quantity has the greatest influence.

Wide and deep bodied hogs tend to dress higher than narrow shallow bodied hogs. Length does not appear to be associated with dressing percent. In conclusion, the variables enumerated influence dressing percent to the extent that they are directly associated with the weight of the components removed from the live hog during the dressing procedure.

Summary

The 201 hogs included in this study consisted of 116 Landrace-Poland crosses, 76 Hampshires and 9 Durocs. Differences between breeds and crosses were not studied.

Hogs slaughtered in the spring had digestive tracts of a lighter weight and a higher dressing percentage than hogs slaughtered in the autumn. The differences in the weight of the digestive tracts and digestive tract contents (fill) had a marked effect upon dressing percent.

Dressing percent was significantly correlated with the yield of carcass trim and leaf fat, four lean cuts plus lean trimmings and the yield of miscellaneous cuts, i.e., feet, tail, kidneys, neck bones and jowls. Per unit yield, the yield of miscellaneous cuts contributed more to dressing percent than the yield of fat and fat more than the yield of lean; nevertheless, the yield of lean contributed more to dressing percent than either the miscellaneous cuts or fat by virtue of a greater percentage yield per carcass.

Dressing percent was significantly correlated with carcass width and depth measurements. Likewise, carcass depth and width measurements were directly correlated. Carcass length was negatively correlated with measurements of carcass depth and width. Carcass length, however, was not significantly correlated with dressing percentage.

The study indicates that dressing percent of hogs can be estimated from carcass measurements as well as from the component yields of cuts from the carcass. The latter appears to be the more reliable of the two methods.

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SIGNIFICANT RELATIONSHIPS IN PORK CARCASS EVALUATION [1, 2]

IV. Loin Equivalents as a Criterion for Live Hog Value

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LIVE hog scores and measurements, yield of primal cuts, yield of fat and other similar evaluations are not entirely adequate in predicting carcass desirability. This is true since they do not, in a coherent way, take into consideration the relative value of the various cuts from the market standpoint. Relationships between carcass measurements and the results of a market desirability and carcass merit study, based on the yield of wholesale cuts, subjective scores and wholesale prices, are presented in this paper.

Materials and Methods

The data for this study came from 207 hogs slaughtered during 1952 and 1953. These consisted of 122 Landrace-Poland crosses, 76 Hampshires and 9 Durocs slaughtered at 205 to 215 lb. live weight.[4] Live hog backfat probes were obtained one day prior to slaughter. Carcass measurements were obtained after the carcasses were chilled 48 hours at 32–35° F. The carcasses were processed as outlined in the Proceedings of the 1952 Reciprocal Meat Conference. As each carcass was processed the preferred cuts (hams, loins, shoulders, and bellies) were subjectively scored by two to five staff members of the Animal Husbandry Department.

The method of scoring described by Gregory and Dickerson (1952) was employed. The scores are based on nine representative pairs of photographs for each cut (one trimmed and one untrimmed). Their rank in degree of finish (fat) was No. 1 the most highly finished, and No. 9 the least finished, with intervening numbers being intermediate. With increasing lean area of each cut, the score increased within a range of 1 to 9.

The wholesale cut scores were expressed as the unadjusted and adjusted loin equivalents which were considered to be a measure of market desirability and, hence, carcass merit. In determining relative carcass merit,

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[2] This research was in cooperation with the Regional Swine Breeding Laboratory, AHRD., ARS., U. S. Department of Agriculture.
[3] Professor Emeritus.
[4] Preslaughter treatment, method of processing and method of determining yields are reported in earlier publications by Zobrisky *et al.* (1959a; 1959b).

the yield of all cuts was expressed in terms of the equivalent yield of trimmed loin.

The wholesale cuts are given the following values: 1.0 for trimmed loin; 0.9 for skinned ham; 0.8 for belly and skinned shoulder; 0.7 for lean trimmings; 0.2 for leaf fat, fat trimmings and backfat; and, 0.1 for "bone". These relative values were used in weighing the percent yield. These approximate relative values for the various cuts are based on average Chicago wholesale prices for a period between 1937 and 1947 as outlined by Gregory and Dickerson (1952).

> "The actual prices of spare ribs and fat would make the items lumped under "bone" worth somewhat more than .1 as much as loin, but variation in yield of "bone" is small relative to other cuts." (Gregory and Dickerson, 1952).

TABLE 1. CALCULATION OF THE UNADJUSTED AND ADJUSTED LOIN EQUIVALENT

1	2	3	4	5	6	7
Cuts	Percent live wt.	Loin equivalent value	Column 2 × Column 3	Av. of committee score	Score value	Column 4 × Column 6
Loin	12.24	1.0	12.240	4	0.95	11.628
Ham	15.36	0.9	13.824	6	1.05	14.515
Belly	10.76	0.8	8.608	8	1.15	9.899
Shoulder	11.32	0.8	9.056	7	1.10	9.962
Lean trim	2.81	0.7	1.967			1.967
Fat trim[a]	17.04	0.2	3.408			3.408
Bone[b]	6.64	0.1	0.664			0.664
		Unadjusted loin equivalent=	49.767[c]		Adjusted loin equivalent=	52.043[c]

[a] Back fat, leaf fat, other fat.

[b] Feet, tail, kidney, spare ribs, neckbone.

[c] The ham, loin, shoulder and belly were scored by a committee. The percent live weight (column 2) of the wholesale cuts from the carcass is multiplied by the equivalent loin value (column 3). Their sum (total of column 4) is referred to as the unadjusted loin equivalent. The unadjusted loin equivalents (column 4) of the four preferred cuts (loin, ham, shoulder and belly) are multiplied by their score (column 5) equivalents (column 6) which yield the adjusted loin equivalents. The sum of the adjusted equivalents (column 7) is referred to as the adjusted loin equivalent.

This is justifiable since it is unlikely that anyone would select hogs for heavier bone to get a high yield of the relatively high priced spare ribs.

The "unadjusted loin equivalent" is adjusted by converting the subjective scores as follows: A score of 9=1.20; 8=1.15; 7=1.10; 6=1.05; 5=1.00; 4=0.95; 3=0.90; 2=0.85; and, 1=0.80. The equivalent yield of loin adjusted for market desirability scores of the cuts is referred to as "adjusted loin equivalent". The procedure employed in calculating the unadjusted and adjusted loin equivalent is given in table 1.

Results and Discussion

Since the unadjusted loin equivalent is an evaluation of carcass merit expressed as a percent, it was desirable to determine if significant relationships existed between this numerical evaluation and backfat measure-

ments. Correlations between the unadjusted loin equivalent and backfat measurements are given in table 2. Carcass backfat measurements as well as live hog probes were negatively correlated with the unadjusted loin equivalent. Correlations between backfat measurements and the unadjusted loin equivalents are expected to be negative. The magnitude of the unadjusted loin equivalent is dependent on the percent yield of individual cuts and the value of these cuts relative to the value of the loin. The subjective numerical scores for quality and meatiness do not enter into unadjusted loin equivalent as shown in table 1.

The relative magnitude of the correlations between the individual live hog backfat probes and the unadjusted loin equivalents in table 2

TABLE 2. CORRELATIONS BETWEEN THE UNADJUSTED LOIN EQUIVALENT AND BACKFAT MEASUREMENTS [a]

Variables	Correlation coefficients	Number of samples
Average of carcass backfat thickness, mm.	—.39	122
Last thoracic backfat thickness, mm.	—.44	137
Lumbar backfat thickness, mm.	—.35	76
Average of the three live hog probes, mm.	—.35	116
Live hog shoulder probe, mm.	—.18	116
Live hog ham probe, mm.	—.29	116
Live hog hip probe, mm.	—.38	116
Shoulder + hip probe ÷ 2	—.29	116
Shoulder + ham probe ÷ 2	—.26	116
Hip + ham probe ÷ 2	—.38	116

[a] All correlations are significant at the 0.01 level except r=—0.18 which is not statistically significant.

closely approximate the correlations between the live hog probes and the yield of the five primal and four lean cuts reported earlier (Zobrisky *et al.*, 1959a). The correlations between the individual live hog probes and the unadjusted loin equivalent, five primal and four lean cuts were: —0.38, —0.32, —0.43 respectively, for the hip probe; —0.29, —0.23, —0.35, respectively, for the ham probe and —0.18, —0.15, —0.21, respectively, for the shoulder probe. The proximity of magnitude of these correlations indicates that the loin equivalent has utility for evaluating pork carcasses and wholesale cuts.

The average quality and meatiness score of the four valued cuts are given in table 3. It should be noted that the preferred cuts from the hogs slaughtered in the autumn scored higher than the preferred cuts from the spring slaughter. Seasonal differences were not checked for their probable significance since the autumn-slaughtered hogs consistently scored higher than spring-slaughtered hogs. A large proportion of the spring-slaughtered hogs had high yielding meaty cuts, but the cuts were lower in quality, lacking firmness, marbling and the desirable, greyish pink color. This was

due, in part, to less finish. The quality and meatiness scores were higher for hogs slaughtered in the autumn; however, the loin equivalents were higher for the hogs slaughtered in the spring (table 3). The reason for this deviation is that each individual cut yielded a greater percentage of the live hog.

The higher dressing percent of the spring slaughtered hogs can be attributed principally to the lighter digestive tract, 13.9 vs. 17.3 lb.; and greater yield of preferred cuts 49.0 vs. 43.5%.

TABLE 3. COMPARATIVE DATA BETWEEN AUTUMN- AND SPRING-SLAUGHTERED HOGS

Item	Autumn (1952)	Spring (1953)
	N=67	N=140
Live wt., lb.	204.3	209.1
Dressing, %	73.5	76.7
Intestinal fill, lb.	3.2	3.1
Empty digestive tract, lb.	14.1	10.8
Preferred cuts, %	43.5	49.0
Total fat, %	19.4	17.4
Unadjusted loin equivalent, %	45.7	48.6
Adjusted loin equivalent, %	47.7	51.6
Average quality and meatiness scores:		
Ham	6.8	5.6
Loin	7.3	5.7
Shoulder	6.3	5.4
Belly	7.3	5.0

Evaluation procedures of live hogs, pork carcasses and cuts often neglect to consider the value of the wholesale cuts from the market viewpoint. The results of this study suggest the possibility of a method whereby quality, quantity and relative value of wholesale cuts can be incorporated into a single index which reflects carcass merit.

Summary

The subjective scores of the preferred cuts and the carcass yields and measurements included in this paper came from 207 hogs slaughtered during the autumn and spring of 1952 and 1953.

Live hog probes and carcass backfat measurements were negatively correlated with the unadjusted loin equivalent. The magnitude of these correlations approximated the correlations between live hog backfat probes and the yield of the five primal and four lean cuts.

The average yield of the carcasses and preferred cuts, respectively, were greater for the hogs slaughtered in the spring, while the average digestive tract was lighter than from hogs slaughtered in the autumn.

The average unadjusted and adjusted loin equivalent evaluations were greater for the hogs slaughtered in the spring.

The preferred cuts from the hogs slaughtered in the autumn were valued higher per unit weight than the spring hogs, because they were superior in firmness, marbling and color. Nevertheless, on the average, carcasses from the hogs slaughtered in the spring were valued higher, due to their greater yield of the preferred cuts and smaller yield of the cuts of lower value.

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EFFECT OF ALKALINE DRINKING WATER ON THE pH AND MICROBIAL ACTIVITY OF THE RUMEN [1]

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THE buffering capacity of ruminal fluid *in vitro* has been investigated by previous workers (Clark and Lombard, 1951; Turner and Hodgetts, 1955) who found this material to be relatively well buffered against the addition of acid, but poorly buffered against the addition of alkali. Clark and Lombard (1951) showed that the addition of large doses of sodium carbonate to the rumen of sheep produced a sharp temporary increase in ruminal pH. These findings suggested the possibility that the ingestion of alkaline drinking water over an extended period of time might overtax the buffering capacity of the rumen and raise ruminal pH to values which are unfavorable for the growth of rumen microorganisms.

The physiological effects of saline and alkaline drinking waters on a number of species of animals have been reported by Heller (1932; 1933); he attributed the undesirable effects of various salts in concentration of 2 to 2.5% to changes in osmotic pressure. Cattle and sheep were included in those studies, but the effects of the poor quality drinking waters on the microbial activities and pH of the rumen were not reported. In view of the current concern over water supplies in many localities and because of the occurrence of alkaline waters in certain areas devoted to livestock production, it appeared to be of practical as well as theoretical interest to know the effects of continued ingestion of highly alkaline drinking water on ruminal pH and on the activity of rumen microorganisms.

Materials and Methods

Two animals were supplied with drinking water of high alkalinity for a period of 16 weeks, during which time ruminal pH was measured in order to determine the effect of continuous ingestion of alkaline water on the buffering capacity of the rumen. Samples of rumen ingesta were removed at various intervals and the ability of the microorganisms to digest cellulose was determined in an artificial rumen to ascertain whether there was a reduction in digestive ability with increased time on the alkaline water. The values obtained were compared with those from control animals and with values which had been obtained from other artificial rumen experiments over a period of several years.

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[4] We are indebted to Dr. R. R. Shrode for assistance with statistical analysis.

Maintenance of Animals. Two fistulated heifers and two young steers without rumen fistulas were used in the investigation. One steer and one heifer were housed together and were given alkaline drinking water. The other steer and heifer were similarly housed and were given water from the campus water supply, previous experiments having shown that rumen contents from animals drinking this water had good microbial activity *in vitro*. Water was supplied *ad libitum* to both pairs of animals.

The ration consisted of 12 lb. of alfalfa hay and 3 lb. of concentrate per animal per day; the concentrate contained a mixture of ground ear corn, ground milo, and cottonseed meal in the ratio of 10:7:3. Salt was fed free-choice in bone meal. After 38 days on experiment, the amount of concentrate was increased to 5 lb. per animal per day. Limited access to pasture (2–3 hr. per day) was permitted during part of the experiment. The animals were fed daily at approximately 6 p.m.

Selection and Composition of Experimental Water. Alkalinity is imparted to water usually by the presence of carbonate, bicarbonate, and hydroxyl ions. While the pH of a solution represents the concentration of hydrogen (and indirectly, therefore, hydroxyl) ions present at any given instant, the term "alkalinity" expresses the total reserve or buffering capacity of the solution (American Public Health Association, Inc., 1955). The experimental water in the present studies had a high pH and was high in total alkalinity, indicating a large instantaneous concentration of hydroxyl ions as well as a high titratable alkalinity.

In order for the results of the experiment to be of practical significance, it was felt that the experimental water should have as high an alkalinity and pH as any waters which are likely to be given to cattle. Inspection of some 2300 water analyses from wells, rivers, and lakes in all geographic areas of Texas and of several hundred analyses of surface waters from other Western states revealed that few had total alkalinities in excess of 500 parts per million (ppm. as $CaCO_3$). Of the 2300 samples from this state, only 90 had alkalinities exceeding this level, and very few indeed had alkalinities above 800 ppm.

The experimental water was obtained from a settling pit where it had drained after being used as a coolant for a heat exchanger. The evaporation produced by the heat exchanger served to increase the ionic concentration and left the water with both a high pH (9.76) and high alkalinity (912 ppm. as $CaCO_3$). It was believed that this water was excellent experimental material because its alkalinity was exceeded by only two of the natural water examined.[5] It was much higher in carbonate than any other water sample examined, a fact which explains its high pH. It appears likely, therefore, that the experimental water had an alkalinity and pH greater than most waters likely to be given to livestock.

The complete analyses of both control and experimental waters are shown in table 1. The experimental water (pH 9.76) had more than 16 times the

[5] These waters had alkalinities of 1000 and 1244 ppm.

hydroxyl ion concentration of the control water (pH 8.54), and, what is more important, it had a total alkalinity some 4.5 times that of the control water as shown by its methyl orange alkalinity. Thus, it had a much greater total acid-neutralizing capacity than the control water.

TABLE 1. ANALYSES OF WATERS DRUNK BY EXPERIMENTAL AND CONTROL ANIMALS

Item	Control water	Experimental (alkaline) water
pH	8.54	9.76
	parts per million	*parts per million*
Phenolphthalein alkalinity as $CaCO_3$	0	222
Methyl orange alkalinity as $CaCO_3$	201	912
Hardness as $CaCO_3$	8.0	8.0
Silica (SiO_2)	13.2	23.6
Iron and aluminum oxides (R_2O_3)	0.8	5.2
Cations:		
Calcium	3.2	3.2
Magnesium	Trace	Trace
Alkali metals as sodium	212	725
Anions:		
Bicarbonate	245	571
Carbonate	0	266
Sulfate	22.2	245
Chloride	172	298
Phosphate	3.8	23.1
Dissolved solids:	672	2158
Hypothetical combinations:		
Calcium bicarbonate	12.9	12.9
Sodium bicarbonate	324	772
Sodium carbonate	0	470
Sodium sulfate	32.8	362
Sodium chloride	284	491

In Vitro Cellulose Digestion Experiments. Samples taken by fistula from both heifers or by stomach tube from both steers were used in each cellulose digestion test. Whenever possible, sufficient rumen contents were collected to fill the sample jars completely in order to exclude air. The jars were then packed in insulated boxes and transported immediately to the laboratory. There the rumen contents were strained through four layers of cheesecloth, then centrifuged at $475 \times g$. for 1 minute to remove vegetable matter. Twenty-five ml. of the supernatant were used to inoculate each fermentation flask.

In vitro fermentations were carried out in 250 ml. centrifuge bottles which were fitted with stoppers and gassing tubes connected to a mani-

fold similar to that described by Bentley *et al.* (1954). The fermentation mixtures contained 800 mg. of cellulose [6] suspended in 50 ml. of double strength medium virtually identical to that described by Cheng, Hall, and Burroughs (1955). To this was added the inoculum of 25 ml. of strained, centrifuged rumen liquid, and the volume was brought to 100 ml. with distilled water. Incubation was carried out at 39° C. for 24 hours during which time the contents of the fermentation bottles were stirred by passing in carbon dioxide. Residual cellulose was determined by the method of Crampton and Maynard (1938). Triplicate or quadruplicate determinations were made on the rumen liquid from each animal in all of the experiments.

Measurements of pH. All determinations of the pH of rumen contents were made with a Beckman Model G pH meter, using a glass electrode and a calomel reference electrode. In order to minimize losses of carbon dioxide with attendant increases in pH, measurements of pH were carried out either by removing rumen contents and making the determination immediately, or by inserting the electrodes directly into the rumen of the fistulated animals. In the latter procedure, efforts were made to avoid surface measurements, and to take readings at several locations within the rumen. The measurements of pH were made at various times during the day, but control and experimental animals were always tested at the same time. Since the animals were fed at the same time and water was supplied *ad libitum,* the only difference in treatment was in the composition of the water which they received.

The values obtained for the pH of rumen contents removed by stomach tube are not reported, since previous workers have found that such samples are usually erroneously high (Clark and Lombard, 1951; Turner and Hodgetts, 1955; Blake *et al.,* 1957).

Results

The animals receiving the alkaline water were normal in health and appearance and gained weight during the experiment.

The ingestion of alkaline water over the 16-week period failed to increase the pH of the rumen contents of the experimental animal to values higher than those of the control. The results in table 2 indicate that pH values in the rumen of the heifer drinking alkaline water were never above neutrality and frequently were lower than those of the animal drinking control water.

Measurements of pH made inside the rumen showed that the hydrogen ion concentration was somewhat lower near the rumen wall. This effect is believed to be due to the absorption of fatty acids by the rumen wall, and to the acid-base exchange of the rumen epithelium (Masson and Phillipson, 1951). These workers found that the reaction of alkaline

[6] Solka-Floc 40A, Brown Co., Berlin, New Hampshire.

TABLE 2. pH VALUES OF RUMEN FLUID FROM ANIMALS RECEIVING DIFFERENT DRINKING WATERS[a]

pH measurement no.[b]	pH of rumen contents in animal on—		Hours after feeding
	Alkaline water	Control water	
1	6.95	6.60	
2	6.66	6.61	23
3	6.55	6.56	21
4	6.20	7.00	17
5	6.24	6.65	
6	6.30	6.50	
7	6.35	6.60	21
8	5.60	5.90	
9	5.50	6.00	
10	6.00	6.20	
11	5.45	5.90	16
12	4.60	5.90	16
13	6.00	6.20	22
Average	6.03	6.35	

[a] Measurements of pH were made on different days beginning when the animals had been receiving their respective water for 31 days, and ending when they had been on experiment for 105 days. The results are listed in chronological order.

[b] Measurements 1, 3, 4, 7, 10, 11, and 12 were made at the times when samples were collected for cellulose digestion tests 3–5 and 9–12, respectively (table 2).

TABLE 3. EFFECT OF DRINKING WATER ON THE MICROBIAL ACTIVITY OF RUMEN LIQUID AS MEASURED BY CELLULOSE DIGESTION *IN VITRO*

Cellulose digestion test no.	Days on experiments	Cellulose digestion by micro-organisms from animals receiving—	
		Alkaline water	Control water
		%	%
	Samples taken from steers		
1	20	20[a]	65
2	25	52	40
6	61	2	28
8	69	41	40
	Samples taken from heifers		
3	31	54	53
4	47	50	6
5	54	71	6
7	61	42	3
9	75	54	32
10	90	27	38
11	95	58	21
12	105	55	59
13	109	51	—

[a] Drenching was necessary in order to obtain a sample from the steer receiving alkaline water. This procedure may have reduced the amount of cellulose digestion by dilution of the inoculum.

solutions introduced into the empty rumen moved rapidly toward neutrality. This mechanism might also be effective during increased ingestion of alkaline substances, since the present experiments showed that the normal buffering capacity in the rumen is sufficient to neutralize alkaline water *in vivo* even though rumen fluid is weakly buffered against alkaline additions *in vitro*.

A total of 13 cellulose digestion tests were carried out *in vitro* over a period of 16 weeks. Four trials were run with rumen contents from the steers, and nine were run with rumen contents from the heifers. The results are summarized in table 3. A direct comparison of two animals in any one test cannot be made because of the probable differences in the population of the inocula. The values for cellulose digestion shown in table 3 for both the control and the experimental animals, however, are in good agreement with those from numerous other artificial rumen experiments done in this laboratory. They demonstrate that the ingestion of alkaline water did not produce conditions of such a nature that the cellulose digesting microorganism were eliminated during the period of the experiment.

Low cellulose digestion values were obtained with the heifer on control water in three tests, and with the steer on experimental water in one test. The reason for these low values is not clear, but in tests 4 and 5 it was observed that the rumen of the control heifer contained virtually no solid material and there appeared to be very little activity within the rumen. The low values in tests 6 and 7 cannot be explained on this basis, but it is likely that they were caused by difficulties in obtaining samples, particularly in test 6 where the sample was taken by stomach tube. Although there was considerable variation between cellulose digestion results, even with inocula from the same animal taken at different times, all values except that for the steer on experimental water in test 6 were within two standard deviations of the mean. Analysis of variance showed no significant difference in cellulose digestion between animals receiving the different waters.

At the close of the experimental period, one additional cellulose digestion test was performed by changing the heifer receiving alkaline water to the control water. Eight days after this change, an *in vitro* test showed 44% cellulose digestion, a value which is similar to those given by this animal while receiving alkaline water.

Discussion

Cheng, Hall and Burroughs (1955) investigated the effects of pH on the digestion of cellulose by washed rumen microorganisms *in vitro*, and found that optimum digestion occurred at pH values ranging from 6.8 to 7.6. Appreciable quantities were digested at pH 5.6, and very good digestion was observed at pH 8.4. These results indicate that the organism

responsible for cellulose digestion have a reasonably wide tolerance toward hydrogen ion concentrations.

In the cellulose digestion tests of the present experiment, the buffers used for the *in vitro* studies would have masked any alkalinity in the inoculum caused by the drinking water. The pH determinations, however, showed that the experimental water did not cause an alkaline reaction in the rumen. Furthermore, if the water had produced conditions *in vivo* which were unfavorable to the propagation of cellulose digesting bacteria, a poor inoculum would have resulted, and the effect would have been reflected in the *in vitro* tests.

On the basis of previous reports, it appears likely that under normal conditions the pH of rumen liquid seldom rises much above neutrality, and that it may frequently drop to pH 5 or below during active fermentation (Kick *et al.*, 1938; Monroe and Perkins, 1939; Smith, 1941; Phillipson, 1942; Myburgh and Quin, 1943; Marston, 1948; Blake *et al.*, 1957; Brethour *et al.*, 1958). Reports in the literature in which ruminal pH values of 8 or above are indicated as being normal may have resulted from samples being unduly exposed to air (Smith, 1941; Myburgh and Quin, 1943; Clark and Lombard, 1951; Turner and Hodgetts, 1955). The mere act of opening a fistula to collect the sample permits the escape of some carbon dioxide; hence, all recorded values for the pH of rumen fluid are likely to be high (Elsden and Phillipson, 1948).

The amounts of alkaline salts ingested with the experimental drinking water were smaller, of course, than the very large doses given to sheep by Clark and Lombard (1951) at a single time, and were insufficient to overcome the buffering capacity of the rumen *in vivo*.

Summary

The ingestion of highly alkaline drinking water by cattle over a period of 16 weeks failed to increase the pH of rumen contents above that of control animals receiving water of much lower pH and total alkalinity. Inocula from animals receiving alkaline water gave *in vitro* cellulose digestion values which were not significantly different from those of animals receiving control water, and which were similar to values from numerous other *in vitro* experiments performed in this laboratory.

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EFFECT OF ESTROGEN AND PROGESTERONE ON EARLY EMBRYONIC MORTALITY IN OVARIECTOMIZED GILTS [1]

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PRENATAL death is an important factor in determining litter size of swine (Hammond 1914, 1921; Corner, 1923) with the most critical period for embryonic survival occurring during the first 25 days of gestation (Squires *et al.*, 1952; Lerner *et al.*, 1957).

Observations which have been made on ovariectomized animals provide information on the influence of progesterone and estrogen on the intra-uterine environment as evaluated in terms of embryonic survival. Lyons (1943) has shown that pregnancy is maintained in ovariectomized rats by the administration of 4 mg. of progesterone and 1 mcg. of estrone daily. Cochrane and Meyer (1957) demonstrated the influence of estrone injections on the occurrence of implantation in ovariectomized rats receiving exogenous progesterone. Foote *et al.* (1957) were able to maintain pregnancy in ovariectomized ewes with progesterone and estrone.

The purpose of this study was to investigate the effect of progesterone and estrogen on early embryonic mortality in ovariectomized gilts. The initial observations made in the reported study were designed to determine the magnitude of early embryonic mortality in untreated gilts maintained in the same herd as the ovariectomized gilts.

Experimental Procedure

Intact Gilts. Studies were made on 42 gilts which were slaughtered at three different stages of the gestation period. Gilts in Group I were slaughtered 1–2 days after the end of estrus, whereas those in Groups II and III were slaughtered 25 and 40 days after mating, respectively.

The 10 gilts assigned to Group I were bred twice daily while in estrus. Fertilization rates were determined in these gilts by flushing the ova from the reproductive tracts collected at the time of slaughter. Ova showing cleavage stages of two or more blastomeres were considered to be fertilized.

The embryonic mortality rate was determined in Groups II and III. These gilts were bred one or more times during estrus and were slaughtered on the 25th or 40th day of pregnancy according to previous group assign-

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[4] Progesterone furnished by A. D. Rankin, D.V.M., The Squibb Institute for Medical Research, New Brunswick, New Jersey. This investigation has been supported by the Rath Packing Co., Waterloo, Iowa; Farmers Hybrid Hogs, Hampton, Iowa and Pioneer Hi-Bred Corn, Des Moines, Iowa.

ment. The embryonic mortality rate was determined by comparing the number of corpora lutea with the number of living embryos present when the gilts were slaughtered. The reproductive tracts were examined within 15 minutes after the gilts were slaughtered which made it possible to classify the embryos as living or dead according to the presence of a heart beat.

Ovariectomized Gilts. Forty gilts were used in this phase of the experiment. All gilts were checked daily for estrus, bred to mature boars and ovariectomized on the 15th day after mating. Daily intramuscular injections of estrogen (estradiol benzoate) and progesterone were administered in sesame oil during a 10-day treatment period extending from the day the gilts were ovariectomized to the 25th day after mating when the gilts were slaughtered. Corpora lutea counts were made at the time of ovariectomy and the uteri were examined for living embryos after the gilts were slaughtered in order to determine the embryonic mortality rates.

Results

The average fertilization rate was 100% in eight gilts slaughtered 1–2 days after the end of the estrus (Group I). An average of 10.7 corpora lutea was found in these gilts and 80% of the ova were recovered. The gilts were bred an average of three times during estrus. Two gilts failed to furnish information on the fertilization rate due to the presence of cystic follicles.

Table 1 shows the embryonic mortality rates found in the intact gilts (Groups II and III). Fourteen of the 32 gilts assigned to Groups II and III were selected from a Poland China line with a record of low reproductive efficiency. However, since there were only small differences found in the average prenatal mortality rate of the Poland China gilts from this line and gilts of other breeding (5% and 2% lower in the Poland China gilts in Groups II and III, respectively), the results presented in table 1 are averaged over breed groups. As shown in table 1, nine gilts slaughtered during early pregnancy had either failed to conceive or had conceived but pregnancy had not been maintained. Three gilts with non-pregnant uteri when slaughtered were found to have cystic ovaries and one gilt weighing 290 lb. had an infantile reproductive tract. No reason was apparent for the non-pregnant condition found in five gilts. However, four of these five gilts had not returned to estrus 25 days after mating which indicates initial pregnancy may have been followed by the prenatal death of the entire litter.

The effect of exogenous progesterone and estrogen on early embryonic mortality in ovariectomized gilts is summarized in table 2.

No hormonal replacement was given three gilts unilaterally ovariectomized but five to nine corpora lutea were present on the intact right

TABLE 1. EMBRYONIC MORTALITY RATES IN INTACT GILTS

Items	Days of pregnancy slaughtered	
	25	40
No. of gilts	22	10
No. pregnant uteri	15	8
Av. no. corpora lutea	12.0	12.9
Av. no. normal embryos	8.0	8.0
Av. no. degenerate embryos	0.3	0.8
Av. mortality rate,[a] %	33.3	37.9
No. non-pregnant uteri	7	2
Gross abnormalities	4	0
No apparent cause	3	2

[a] Expressed as the percentage of corpora lutea represented by living embryos on the day of slaughter.

ovary. As shown in table 2, pregnancy was maintained in the gilts unilaterally ovariectomized but the embryonic mortality rate was 74%.

Three gilts bilaterally ovariectomized on the 15th day of pregnancy did not receive any hormonal treatment. None of these gilts were pregnant when slaughtered on the 25th day of gestation. The uteri collected from these gilts at the time of slaughter had the general appearance of the uterus of a sexually immature gilt. Two of the three gilts in this treatment group were given daily injections of sterile sesame oil at a level of 4 ml. per 100 lb. body weight during the 10-day treatment period. The other gilt was not injected.

Pregnancy was not maintained in two gilts given daily injections of estradiol benzoate. In contrast, daily progesterone injections were found to be capable of producing uterine conditions necessary for the maintenance

TABLE 2. EMBRYONIC MORTALITY RATES IN OVARIECTOMIZED GILTS ADMINISTERED VARIOUS LEVELS OF PROGESTERONE AND ESTRADIOL BENZOATE

Progesterone[a]	Estradiol benzoate[a]	Gilts treated	Av. weight	Av. no. corpora lutea	Gilts pregnant at 25 days	Av. no. normal embryos	Av. no. degenerate embryos	Av. mortality rate
mg.	mcg.		lb.					%
0	0	3[b]	235	13.0	3	3.3	3.3	74
0	0	3	218	10.3	0	...	0.0	..
0	50	2	217	10.0	0	...	0.0	..
15	15	1	234	12.0	0	...	0.0	..
50	0	2	231	12.0	2	6.5	1.0	46
50	25	1	246	12.0	1	3.0	5.0	75
50	50	2	233	10.0	2	7.5	0.0	25
75	0	2	259	16.0	2	6.5	1.5	59
75	75	2	226	11.5	1	1.5	3.0	77
100	0	3	230	12.3	2	4.7	0.0	39
100	50	17	234	11.6	13	8.8	0.8	22
100	100	1	227	9.0	1	8.0	0.0	11
100	500	1	212	8.0	0	...	0.0	..

[a] Expressed as daily dose per 100 lb. body weight.
[b] Unilateral ovariectomy; all other gilts listed were bilaterally ovariectomized.

of pregnancy in ovariectomized gilts during the 10-day treatment period. As shown in table 2, progesterone administered at the daily rate of 100 mg. per 100 lb. body weight appeared to be slightly more effective in preventing early embryonic mortality than either the 75 or 50 mg. levels. One of the seven gilts injected with progesterone was not pregnant when slaughtered but nine degenerating embryos found in the uterus showed conception had occurred.

An estrogen-progesterone combination was generally found to be more effective in promoting embryonic survival in ovariectomized gilts than either hormone administered alone. However, the effectiveness of this combined hormonal treatment varied considerably with the ratio used and also with the level injected at each ratio studied. The estrogen-progesterone ratios employed were 1:100, 1:1000 and 1:2000. The results obtained at the different dose levels in the initial phase of the experiment indicated the daily injection of 50 mcg. of estradiol benzoate and 100 mg. of progesterone (ratio 1:2000) was highly effective in inducing optimum uterine conditions for embryonic development. Therefore, this level was used in making a more intensive evaluation of the relationship between these hormones and early embryonic mortality. As shown in table 2, 17 ovariectomized gilts received a daily injection of 50 mcg. of estrogen and 100 mg. of progesterone per 100 lb. body weight during the 10-day treatment period. The average embroyonic mortality rate in the 13 gilts pregnant when slaughtered on the 25th day of gestation was 22%. This mortality rate is 11% less than the average prenatal death loss found in a similar group of 15 untreated, intact gilts slaughtered at the same stage of pregnancy.

Discussion

The loss of ova due to non-fertilization appears to be of minor significance in reducing litter size in gilts. The high fertilization rate found in the present study is in agreement with observations made by Squires *et al.* (1952) who reported the average fertilization rate in 52 matings was 95% and in 37 of these 52 matings 100% of the ova were cleaved.

Embryonic mortality prior to the 25th day of gestation was found to be a major factor in determining litter size at farrowing. The average embryonic mortality rate was found to be 33% in gilts having one or more living embryos on the 25th day after mating and 38% in gilts slaughtered on the 40th day of pregnancy. Similar results have been presented by Squires *et al.* (1952), Rathnasabapathy *et al.* (1956) and Lerner *et al.* (1957). Therefore, it appears that approximately one-third of the ova ovulated are not represented by normal embryos 25 days after mating even though the fertilization rate approaches 100%. This high prenatal death loss during early pregnancy indicates the physiological condition of the uterus during the early development and the implantation of embryos is one of the main factors involved in determining the degree of embryonic survival for the entire gestation period.

Pregnancy was not maintained in gilts ovariectomized during early pregnancy unless a hormonal replacement containing progesterone was administered. Estradiol benzoate injections apparently did not induce the uterine conditions required for embryonic survival in ovariectomized gilts but pregnancy was maintained in six of seven ovariectomized gilts given daily injections of progesterone during the 10-day treatment period. However, ovariectomized gilts injected with progesterone alone showed a high embryonic mortality rate. These results indicate that the optimum intra-uterine conditions necessary for embryonic survival were not induced by the progesterone injections. Studies made on intact gilts by other investigators indicate added progesterone injected at low levels during early pregnancy does not influence litter size and that high levels may even decrease embryonic survival. Sammelwitz *et al.* (1956) injected gilts with progesterone at the rate of 50, 100, 200 and 400 mg. daily for about 26 days after mating. At the time of slaughter 92% of the ova had survived in the control group, 87% in the 50-mg. group and 64.9% in the 100-mg. group. The corpora lutea were completely degenerated by the time of slaughter in some of the sows in the 200-mg. group and in all sows in the 400-mg. group. Haines *et al.* (1957) reported injections of 25 mg. of progesterone every other day during the first 25 days of pregnancy did not reduce embryonic mortality in gilts.

The lowest rate of embryonic mortality observed in the present study was in ovariectomized gilts receiving both estrogen and progesterone between the 15th and 25th day of gestation. Previous investigations by Lyons (1943) and Cochrane and Meyer (1957) demonstrated the requirement of estrone, in addition to progesterone, for embryonic survival in ovariectomized rats. In a study of hormonal therapy on embryonic survival in intact gilts, Reddy (1957) showed the desirability of using a combination of exogenous progesterone and estrone to decrease prenatal mortality during early pregnancy. Gilts given daily injections of 12.5 mcg. of estrone and 25 mg. of progesterone (ratio 1:2000) for 10 consecutive days, beginning on the 14th day of pregnancy, had an average embryonic mortality rate of 13.5% at the 56th day of gestation. The average prenatal death loss observed in the control gilts was 23.3%. In the present study, the administration of 50 mcg. of estradiol benzoate and 100 mg. of progesterone per 100 lbs. of body weight was found to be especially effective in promoting an intra-uterine environment conducive to embryonic survival in ovariectomized gilts. This ratio of estrogen and progesterone (1:2000) was also used by Reddy (1957) who reported a 1:1000 ratio of estrone and progesterone was decidedly inferior to a 1:2000 ratio in reducing early embryonic mortality in intact gilts. Although it appears evident a synergism exists between estrogen and progesterone in promoting conditions conducive to embryonic survival in gilts, this beneficial effect of an estrogen-progesterone combination appears to be confined to a wide ratio between

the hormones and also to an adequate level of the hormones combined at the optimum ratio.

It seems apparent from these results that the excess or deficiency of one or both of these hormones, estrogen and progesterone, results in uterine conditions unfavorable for early embryonic survival and, in turn, it appears this hormonal imbalance may be one of the primary causes of the high embryonic death rate occurring in swine.

Summary

Studies have been made on early embryonic mortality in swine. All ova recovered from eight bred gilts slaughtered 1 to 2 days after the end of estrus showed cleavage stages of two or more blastomeres. Thirty-three percent of the corpora lutea counted in 15 pregnant gilts at the 25th day after mating were not represented by normal embryos. The average embryonic mortality rate observed in eight gilts slaughtered on the 40th day of pregnancy was 38%.

The effect of progesterone and estrogen, administered intramuscularly in sesame oil, on embryonic survival was evaluated in pregnant gilts ovariectomized on the 15th day after mating and slaughtered on the 25th day of gestation. Thirty-four ovariectomized gilts were injected with various levels of progesterone and estradiol benzoate daily during this 10-day period. The results obtained indicate estradiol benzoate alone will not maintain pregnancy in gilts and progesterone alone is not as effective in producing optimum intra-uterine conditions for embryonic survival as is a combination of progesterone and estradiol benzoate. Thirteen out of 17 ovariectomized gilts injected daily with 100 mg. of progesterone and 50 mcg. of estradiol benzoate per 100 lb. of body weight were pregnant when slaughtered. The average embryonic mortality rate in these 13 gilts at 25 days of pregnancy was 22% or 11% less than that observed in 15 intact gilts slaughtered at the same stage of pregnancy.

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EFFECT OF GLYCEROL EQUILIBRATION TIME, GLYCEROL LEVEL, AND RATE OF TEMPERATURE DESCENT ON THE FREEZING OF RAM SPERMATOZOA [1, 2]

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THE sub-zero freezing of ram spermatozoa has been investigated only to a limited extent. Emmens and Blackshaw (1950) reported that ram semen would survive after freezing to —79° C. if frozen slowly in extenders containing mixtures of glycerol and arabinose. White *et al.* (1954) observed that ram semen extended in glycerol had lower survival following freezing than did semen extended in mixtures of glycerol and pentose. Emmens and Blackshaw (1955) reported a 5% conception rate when using frozen ram semen. First *et al.* (1957) obtained a 17% conception rate when ewes were inseminated with frozen ram semen extended in a milk extender containing 7% glycerol and 1.25% arabinose.

The object of this experiment was to determine the effects of different glycerol levels (3.5, 5.25, 7 and 14% glycerol), equilibration times (0.5 and 18 hours) and rates of freezing (slow and rapid) on ram spermatozoa frozen and stored at —79° C.

Experimental Procedure

This study was divided into two parts. Part I was a comparison of different glycerol levels and equilibration times; Part II was a comparison of two rates of freezing. Part I was further sub-divided into trials 1 and 2, each testing simultaneously the three factors; equilibration times, glycerol levels, and rams in completely randomized $2 \times 3 \times 4$ factorial experiments. Part II was a $2 \times 2 \times 4$ factorial experiment designed to test differences in rate of freezing, storage times, and rams. Statistical procedures followed those outlined for factorial arrangements of treatments by Snedecor (1957).

The extender used in this experiment was composed of 20% egg yolk and 80% of a 3% sodium citrate solution. Antibiotics were added as streptomycin sulfate (1,000μ g./cc. of extender) and potassium penicillin G. (1,000 Oxford units/cc. of extender). Semen was collected in an artificial vagina from one Hampshire and three Suffolk rams. An average

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[2] A portion of the dissertation presented by the senior author to the Graduate School of the Clemson Agricultural College, Clemson, S. C. in partial fulfillment of the requirements for the M.S. degree.

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of one collection per week was made from each ram during the period December 1, 1957 to February 3, 1958.

Semen, after collection, was extended 1:25 in an egg yolk-citrate diluter held at 27–32° C. The diluter with the semen was then allowed to cool to 4° C. over a 4-hour period. At this temperature a glycerolated egg yolk-citrate diluter containing twice the final desired concentration of glycerol was added to double the volume of the semen containing diluter. This gave a final semen extension of 1:50. The glycerolated extender was added to the extender containing semen in three steps at 15-minute intervals; first step, 20% by volume; second step, 30%; and third step, 50%.

Freezing was accomplished by adding powdered dry ice to an alcohol bath which contained sealed glass ampules of semen. Following freezing to —79° C., the ampules were stored in a Fros-T [4] electro-ice frozen semen chest. The semen was thawed by placing the ampules in ice water. The semen was examined under a microscope (300X) and ratings were made in intervals of 10 between 0 and 100%. Motility ratings were then converted to percent recovery by the following formula:

$$\text{Percent Recovery} = \frac{\%\ \text{Motility at thawing}}{\%\ \text{Initial motility}} \times 100$$

Results and Discussion

Part I. Trial 1. In trial 1 the effects of 3.5, 7, and 14% glycerol were studied simultaneously with 0.5-hour and 18-hour equilibration times. During freezing, the temperature was lowered 2° C. per minute from 4° C. to —20° C., 4° C. per minute from —20° C. to —50° C., and 10° C. per minute from —50° C. to —79° C. The results are based on the percent recovery of sperm cells after 48 hours or 10 days storage at —79° C. (table 1).

The highest percent recovery was obtained in semen extended in a 7% glycerol extender. The lowest percent recovery occurred when 14% glycerol was used. Percent recovery in all levels of glycerol decreased between 48 hours and 10 days. Separate analyses were made for the two storage periods. Analyses of the 48-hour and the 10-day data revealed significant differences among glycerol levels ($P<.05$). By making orthogonal comparisons, 14% vs. 3.5 and 7%, and 3.5 vs. 7%, no significant difference was revealed between 3.5 and 7% glycerol. There was a highly significant difference in recovery between the 14% glycerol and the others. The results are similar to those of Vandemark *et al.* (1957) with frozen bull semen, who reported that the best survival was obtained when a 6 to 8% glycerol level was used. First *et al.* (1957) reported greatest survival of ram spermatozoa at levels of 6 to 8% glycerol in milk diluters.

The variation between equilibration times was not significant after

[4] Fros-T Electro-Ice Frozen Semen Chest furnished through the courtesy of NOBA, Inc., Tiffin, O.

TABLE 1. PERCENT RECOVERY OF RAM SPERMATOZOA AFTER 48 HOURS AND 10 DAYS STORAGE AT −79° C.

Glycerol level	0.5 hours equilibration		18 hours equilibration	
	48 hours	10 days	48 hours	10 days
%	%	%	%	%
		Trial 1		
3.50	26.7	21.2	27.7	15.9
7.00	41.0	37.2	27.8	26.5
14.00	10.8	9.4	17.0	9.9
		Trial 2		
3.50	58.6	51.4	38.6	45.0
5.25	58.6	60.9	46.9	52.1
7.00	55.0	44.3	55.0	42.6

either period of storage, but the mean percent recovery of semen was higher for the 0.5-hour than for the 18-hour equilibration time.

After 48 hours storage, semen extended in 3.5 and 14% glycerol and equilibrated for 18 hours gave higher percent recovery than did comparable semen equilibrated for 0.5 hour before freezing; however, the 7% glycerol level gave higher percent recovery when 0.5 hour was allowed for equilibration. The glycerol x equilibration interaction approached significance at the 0.05 level. After 10 days storage, 3.5% and 7% glycerol gave higher percent recovery if only 0.5 hour was allowed for equilibration. The percent recovery of semen in 14% glycerol was improved by the 18-hour equilibration time.

Equilibration time is the period between the addition of glycerol and the freezing of spermatozoa. The optimal length of this period is still a questionable issue. Emmens and Blackshaw (1955) compared bull semen that had been equilibrated overnight with non-equilibrated bull semen and found that the equilibrated semen had the highest fertility. Markovic (1956) found survival rates of 60% provided 6 to 14 hours were allowed for equilibration before freezing ram semen. O'Dell and Almquist (1957) found no statistical difference in recovery rates of bull semen that had equilibrated for periods of 0.5 hour, 4 hours and 18 hours. O'Dell and Hurst (1956) compared 0.5-hour and 18-hour equilibration times for freezing bull semen and found higher survival rates in the semen equilibrated only 0.5 hour. Vandemark *et al.* (1957) found that 6 hours equilibration time was significantly better than 2 or 18 hours for equilibrating bull semen.

The percent recovery of all treatments decreased between 48 hours and 10 days. This is in agreement with the results reported by O'Dell and Hurst (1956) when studying bull semen. The highest percent recovery of all treatment combinations after 10 days storage was obtained when

the semen was extended in 7% glycerol and allowed 0.5 hour for equilibration.

Ram differences were significant ($P<0.05$) after 48 hours storage, but the differences among rams after 10 days were not significant. A possible explanation is that some samples of semen had a zero percent recovery after 10 days storage. Thus, the differences among rams became smaller as the percent recoveries approachd zero. During these trials ejaculates that had an initial motility below 30% were discarded. The analyses of variance were based on the average percent recovery of

TABLE 2. PERCENT RECOVERY MAINTAINED BY RAM SPERMATOZOA AFTER THAWING FROM −79° C. TO 4° C. (TRIAL I)

Equilibration time	0.5 hour			18 hours		
Glycerol level	3.5%	7%	14%	3.5%	7%	14%
Days of storage after thawing	Samples stored at −79° C. for 48 hours					
0	26.7	41.0	10.8	27.7	27.8	17.0
1	21.9	23.8	5.6	16.5	12.9	3.4
2	13.5	9.1	0	7.5	9.5	1.9
3	1.6	1.6		4.1	1.9	1.9
4	0	0		0	0	0
	Samples stored at −79° C. for 10 days					
0	21.2	37.2	9.4	15.9	26.5	9.9
1	9.5	18.2	9.1	9.5	22.0	6.5
2	5.3	12.1	1.9	3.4	7.1	3.4
3	3.7	5.6	1.9	1.9	5.6	1.9
4	0	0	0	0	0	0

all ejaculates from each individual ram which tended to lessen the variance between rams. No interactions were significant in trial 1.

The longevity of all samples thawed 48 hours or 10 days after freezing was studied at 4° C. until death of all cells occurred (table 2). It is obvious from inspection of these data that none of the thawed semen maintained good motility in storage. The average longevity of the sperm cells after thawing appeared to be about the same for all treatments except for the semen extended in 14% glycerol, equilibrated for 0.5 hour and stored for 48 hours. These samples reached zero readings on the second day, whereas the other samples reached zero 4 days after thawing. Based on longevity there appears to be very little difference among the various treatment combinations.

Part I. Trial 2. Since there was a significant difference between 14% glycerol and 3.5 and 7% in trial 1, the 14% level was replaced by a 5.25% glycerol level. The 0.5-hour and 18-hour equilibration times were used as in trial 1.

In some samples the percent recovery after 10 days was higher than after 48 hours storage (table 1). The exact cause of this increase in percent recovery between 48 hours and 10 days is not known; however, similar increases have been recorded in studies of bull semen (Polge *et al.*, 1949; Etgen *et al.*, 1957).

Etgen *et al.* (1957) reported higher motilities after 3 weeks of storage at —96° C. than in the same samples after 1 week. They gave two possible explanations. One is that some adjustment period is needed for sperm to respond to the freezing and thawing processes. Another is that sperm disintegrate during the first few weeks of storage. If the latter explanation which appears to be logical is true, the disintergrated sperm cells may not appear during microscopic examination following thawing; thus, the ratio of live to dead cells may be changed.

In trial 2 the glycerol effects were not significantly different. These findings substantiate those in trial 1 in which there were no significant differences between 3.5 and 7% glycerol. Although the variation between glycerol levels is not statistically significant, the percent recovery of semen extended in 5.25% glycerol is highest for both the 48-hour and 10-day storage periods.

Analysis of the 48-hour data revealed a highly significant difference between equilibration times ($P<0.01$). The mean percent recovery was highest for the 0.5-hour equilibration period. The 10-day analysis did not indicate a significant difference between equilibration times. These results indicate that possibly during the 18-hour equilibration period before freezing the sperm cells are damaged to some extent. This loss in recovery causes the differences between the two equilibration periods to appear larger at 48 hours than after 10 days, at which time the differences become smaller.

In trial 2 ram differences were highly significant ($P<0.01$) at 48 hours and 10 days. These ram differences were large because of the wide variation between the initial motilities of ejaculates used. Selection of the ejaculates to be used was practiced as in trial 1; however, this eliminated only the samples with an initial motility of less than 30%. In this trial, (trial 2), extremely high initial motilities for semen from two rams tended to increase ram differences. White *et al.* (1954) found a significant difference between ejaculates in experiments with bull semen. O'Dell and Hurst (1956) found significant differences among both bulls and ejaculates after freezing.

Analysis of the 48-hour data did not reveal any significant interactions; however, the 10-day analysis indicated that the ram x glycerol interaction was highly significant ($P<0.01$). This was probably due to the high percent recoveries obtained when semen from one ram was extended in 5.25 and 7% glycerol. Several ejaculates from this ram had extremely high initial motilities and maintained excellent motility after freezing. This interaction was not significant in trial 1.

TABLE 3. PERCENT RECOVERY MAINTAINED BY RAM SPERMATOZOA AFTER THAWING FROM —79° C. TO 4° C. (TRIAL 2)

Equilibration time	0.5 hour			18 hours		
Glycerol level	3.5%	5.25%	7%	3.5%	5.25%	7%
Days of storage after thawing	Samples stored at —79° C. for 48 hours					
0	58.6	58.6	55.0	38.6	46.9	55.0
1	52.8	50.5	51.7	37.4	46.9	42.6
2	25.0	38.6	27.8	11.9	26.2	11.9
3	11.1	23.1	13.6	4.8	2.4	0
4	5.6	4.8	2.4	2.4	4.8	
5	0	0	0	0	0	
	Samples stored at —79° C. for 10 days					
0	51.4	60.9	44.3	45.0	52.1	42.6
1	43.8	46.2	34.3	32.6	45.7	39.8
2	32.6	32.6	23.1	16.7	19.1	14.3
3	11.9	2.4	9.5	4.8	4.8	4.8
4	2.4	0	2.4	0	0	0
5	0		0			

The longevity of all samples was studied as in trial 1. The daily percent recovery of all samples is shown in table 3. As in trial 1, the data indicated that the longevity of the semen was affected very little by the various treatments. In this trial the average life of the samples was about a day longer than in trial 1; however, there appears to be more variation among the various treatments than occurred in trial 1.

Part II. In part II two different rates of freezing were compared (table 4). One rate of freezing lowered the temperature 2° C. per minute from 4° C. to —20° C., 4° C. per minute from —20° C. to —50° C., and 10° C. per minute from —50° C. to —79° C. The other rate of freezing lowered the temperature 2° C. per minute from 4° C. to a temperature cold enough to crystallize the extender (about —14° C.); from the point of crystallization the temperature was lowered 10° C. per minute to

TABLE 4. THE EFFECT OF RATE OF FREEZING ON THE PERCENT RECOVERY OF RAM SPERMATOZOA AFTER 48 HOURS OR 10 DAYS STORAGE AT —79° C.

Rate of freezing	Storage time	
	48 hours	10 days
Slow [a]	72.9	51.2
Rapid [b]	67.6	41.2

[a] Temperature lowered 2° C. per minute from 4° C. to —20° C., 4° C. per minute from —20° C. to —50° C., and 10° C. per minute from —50° C. to —79° C.

[b] Temperature lowered 2° C. per minute from 4° C. to —14° C., 10° C. per minute from —14° C. to —50° C., and 20° C. per minute from —50° C. to —79° C.

—50° C. and 20° C. per minute from —50° C. to —79° C. The point of crystallization was determined by removing an ampule of extender every 2° C. until the extender became solid. In this phase all of the semen samples were extended in a 7% glycerol extender and equilibrated 0.5 hour before freezing. Split ejaculates were frozen by the two methods and stored at —79° C. for 48 hours or 10 days. The analysis of these data revealed that the differences between the freezing rates were not significant, but the mean percent recovery for the slower rate of freezing was higher than that for the more rapid rate of freezing.

The analysis indicated a significant ($P<0.05$) decline in percent recovery between 48 hours and 10 days. The percent recovery after 48 hours does not appear to be a good indicator of the percent recovery which may be obtained after a longer storage period.

Ram differences were not significant, and interactions were not significant.

Summary

Using an egg-yolk-citrate extender, a study was made to determine the effects of different glycerol levels, equilibration times, and rates of freezing on the freezing, storage, and subsequent recovery of ram semen. Analysis of variance of these data indicated that ram spermatozoa frozen and stored at —79° C. had the highest percent recovery when 3.5, 5.25 and 7% glycerol levels were used. Concentrations of 14% glycerol greatly decreased survival after freezing. Under the conditions of this experiment, a 0.5-hour equilibration time was superior to an 18-hour equilibration period.

There was no statistical significance between two rates of freezing; however, the semen frozen 2° C. per minute from 4° C. to —20° C., 4° C. per minute from —20° C. to —50° C. and 10° C. per minute from —50° C. to —79° C. had a higher percent recovery as compared to semen frozen more rapidly. There was a significant decline in percent recovery between 48 hours and 10 days storage.

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EFFICIENT ESTIMATES OF HERITABILITY FROM PATERNAL HALF-SIB CORRELATIONS [1, 2]

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OVER the past years, many estimates of heritability have been obtained from paternal half-sib correlations. Such estimates are subject to large sampling errors and extensive data must be used if accurate heritabilities are to be calculated.

One formula expressing the standard error of an estimate of an intra-class correlation coefficient is discussed by Fisher (1952) viz:

$$S_r = \frac{(1-r)\left[1+r(k-1)\right]}{\sqrt{\frac{1}{2}(k-1)bk}} \qquad (1)$$

where S_r = the standard error
r = the estimated intra-class correlation coefficient
b = the number of classes
k = the number of individuals within classes (same in all the b classes, $k>1$)

Clearly, the total number of individuals in the sample, n, is given by b x k. It is thus possible to deduce from formula 1

$$n = \frac{2(1-r)^2\left[1+r(k-1)\right]^2}{(k-1)S_r^2} \qquad (2)$$

Formula 1 has been used to estimate the standard error of heritability estimates, S_h, obtained from half-sib relationships (Hazel and Terrill, 1945). In this case

$$h^2 = \frac{4r}{1+F'} \quad \text{and} \quad S_h = \frac{4S_r}{1+F'}$$

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[2] This manuscript was developed by G. M. Tallis and was taken in part from a dissertation presented by him to the Graduate School, The Ohio State University, in partial fulfillment of the Ph.D. degree in 1957. Present address is C.S.I.R.O., McMaster Animal Health Laboratory, Glebe, Sydney, Australia.

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where F′ is the average coefficient of inbreeding of the sires, and h^2 is the estimated heritability.

With the aid of formulae 1 and 2, it is possible to investigate the following questions: (1) What is the minimum number of animals which must be studied in order to estimate heritability to a given accuracy? (2) When the number, n, of animals studied must be restricted to N, what combination of b and k gives the most efficient estimate of heritability?

Problem 1. An inspection of formula 2 reveals that, when Sr is held constant, n is a function of k and r. If environmental correlation is disregarded, r could have a theoretical range of

$$0 \leq r \leq .5$$

in half-sib data when the inbreeding of the sires is considered. However, the range which is of prime interest is

$$0 \leq r \leq .25.$$

$$\text{Now } n\Big|_{r=.25} = \frac{9(k+3)^2}{128(k-1)S_r^2} > n\Big|_{r=0} = \frac{2}{(k-1)S_r^2} \quad [k > 2]$$

Moreover, the value of r which makes n a maximum, r′, is given by the equation

$$r' = \frac{k-2}{2(k-1)} \quad [k > 1]$$

and consequently $r' \geq .25$, $k > 2$..

Therefore, over the specified range of r, n is a monotone increasing function of r for all values of k greater than 2. This means that the number of animals required to estimate heritability to a given degree of accuracy depends on the heritability level, and this number increases as heritability goes from 0 to 1.

This result is more plausible when consideration is given to the ratio $\frac{r}{Sr}$. Clearly, if Sr is fixed and r is allowed to vary from 0 to .25, the value of the ratio increases. Thus, under the null hypothesis that r is zero, the larger values of r are statistically more significant (in terms of standard deviations) than smaller values. It is therefore not surprising that greater numbers of animals are required to obtain the higher significance levels of large r values.

A similar analysis may be made with respect to the variable k. When $\frac{\partial n}{\partial k}$ is calculated and equated to 0, it is found that n is minimized when $k = \frac{1+r}{r} = k'$. This means that each level of heritability has its own

optimum value of k,k′. If other values of k are used, n must inevitably be larger if heritability is to be estimated with the same accuracy. Values of k′ are given in table 1.

TABLE 1. VALUES OF n′, k′ AND b′ FOR DIFFERENT LEVELS OF HERITABILITY (F′=0)

		Sh=·05		Sh=·10		Sh=·15	
h^2	k′	b′	n′	b′	n′	b′	n′
·1	41	30	1230	7	287	3	123
·2	21	110	2310	28	588	12	252
·3	14	235	3290	60	840	27	378
·4	11	377	4147	94	1034	42	462
·5	9	544	4896	136	1224	60	540
·6	8	694	5552	165	1320	73	584
·7	7	871	6097	207	1449	92	644
·8	6	1092	6552	273	1638	121	726
·9	5	1388	6940	384	1920	171	855

The optimum number of offspring per sire decreases with increasing heritability. However, it is now possible to calculate the minimum number, n′, of animals necessary to estimate heritability with a certain standard error, Sh. We summarize now the relationships used above:

$$k' = \frac{1+r}{r}, \quad r = \frac{(1+F')h^2}{4}, \quad S_r = \frac{(1+F')S_h}{4}$$

$$\text{and } n' = \frac{2(1-r)^2\left[1+r(k'-1)\right]^2}{(k'-1)S_r^2}$$

For example, let $F' = 0$

$h^2 = .4$

$S_h = .05$

then $r = .1$, $k' = 11$, $S_r = .0125$ and

$$n' = \frac{2(1-.1)^2\left[1+.1(11-1)\right]^2}{(11-1)(.0125)^2}$$

$$= 4,147$$

As $n = kb$, the optimum number of sires is $b' = \frac{n'}{k'}$. In this manner table 1 may be constructed. Attention is drawn to the fact that the values appearing in the table are only close approximations to the true values because k′ has been calculated to the nearest integer.

The results of this section agree well with the findings of Koch (1957), who examined the efficiency of different values of k and b for estimating heritability to a given degree of accuracy. Such a study is made possible by setting Sr and r, allowing k to vary and computing values of n from formula (2). As $b = \frac{n}{k}$, different combinations of b and k may be calculated and, together with n, compared with n′, b′ and k′ for the particular level of heritability under investigation.

Problem 2. In usual practice, the highest possible value of n is determined by economic factors. Thus, Sr becomes the independent variable (formula 1) and just like n, Sr increases as h^2 goes from 0 to 1 and is minimized for a given heritability when $k = \frac{1+r}{r} = k'$.

Hence, when n is set at a specific value, N, the number of offspring per sire to study for a given degree of heritability, h^2_i, is k'_i, and the optimum number of sires to use is $\frac{N}{k'_i} = b'_i$

The discussion thus far has neglected the fact that, usually, the heritabilities of several characteristics are to be estimated individually from data obtained on one group of animals. As the heritability of these characteristics is likely to vary widely, and because k′ changes with the level of heritability, the question arises as to which value of k, k'_o, to use under these circumstances. A solution to this problem may be obtained as follows, if it is assumed that

$$\sum_{i=1}^{a} \sum_{j=1}^{a} \mathrm{Cov}(r_i r_j), \; i \neq j,$$

is insignificantly small. Let h^2_i $(i = 1, 2, \cdots a)$ be the heritability of the i^{th} characteristic, then $r_i = \frac{(1+F')}{4} h^2_i$. One criterion for selecting an efficient k value would be such that $\sum_{i=1}^{a} S^2_{ri}$ is a minimum. For this to obtain, $\frac{\partial \sum_{i=1}^{a} S^2_{ri}}{\partial k}$ must be equated to zero and solved for k.

We have

$$\sum_{i=1}^{a} S_{r_i}^2 = \sum_{i=1}^{a} \frac{2(1-r_i)^2\left[1+r_i(k-1)\right]^2}{(k-1)_n}$$

and

$$\frac{\partial \sum_{i=1}^{a} S_{r_i}^2}{\partial k} = \sum_{i=1}^{a} \frac{2(1-r_i)^2}{n}\left[\frac{2r_i\left[1+r_i(k-1)\right]}{(k-1)} - \frac{\left[1+r_i(k-1)\right]^2}{(k-1)^2}\right] = 0$$

$$= \sum_{i=1}^{a} (1-r_i)^2\left[r_i^2(k-1)^2 - 1\right] = 0$$

whence

$$k'_0 = \sqrt{\frac{\sum_{i=1}^{a}(1-r_i)^2}{\sum_{i=1}^{a}(1-r_i)^2 r_i^2}} + 1 \qquad (3a)$$

If it were found desirable to weight individual characteristics (according to economic value and/or according to the reciprocal of the variances of the individual r estimates used in computing k'_0), some weighting factor, v, could be calculated for each characteristic. The formula for k′ would then be,

$$k'_0 = \sqrt{\frac{\sum_{i=1}^{a}(1-r_i)^2 v_i}{\sum_{i=1}^{a}(1-r_i)^2 r_i^2 v_i}} + 1 \qquad (3b)$$

A certain amount of circumlocution is unavoidable if use is to be made of formulae 3a and 3b. For instance, an investigator who can study 1,000 animals intends to estimate the heritability of seven characteristics. Moreover, he wishes to know the number of offspring per sire which will maximize the efficiency of his experiment. His first task is to obtain a rough estimate of the heritability of each trait from previous work. Once this information is available, he may proceed as shown below.

Characteristic	Estimated h^2 (Literature)	r, (F′=0)
A	.2	.05
B	.2	.05
C	.4	.10
D	.4	.10
E	.8	.20
F	.8	.20
G	.8	.20

From these figures k'_o may be calculated.

$$k'_o = \sqrt{\frac{2(.95)^2 + 2(.9)^2 + 3(.8)^2}{2(.95)^2(.05)^2 + 2(.9)^2(.1)^2 + 3(.8)^2(.2)^2}} + 1 \leq 9$$

This example assumes a constant economic value for all characteristics and a constant standard error of r.

Apparently, 9 offspring per sire are desirable and he will need approximately 111 sires $\left(\frac{1,000}{9}\right)$. Furthermore, he can expect to estimate the heritability of the i^{th} characteristic with a standard error of

$$S_{h_i} = \frac{4S_{r_i}}{1+F'} = \frac{4(1-r_i)[1+r_i(k'_o-1)]}{(1+F')\sqrt{\frac{1}{2}n(k'_o-1)}}$$

Thus, Sh for A and B is likely to be close to

$$\frac{4(1-.05)[1+.05(9-1)]}{\sqrt{\frac{1}{2} \times 1,000(9-1)}} \leq .08$$

Similarly, expected Sh's for the second group (C, D) and for the third group (E, F, G) are 0.10 and 0.14, respectively. Analogous but somewhat simpler reasoning is required to utilize table 1.

As a final illustration of these methods, suppose we wish to know what minimum value of n, n'_o, satisfies the conditions

$$\sum_{i=1}^{a} S^2_{r_i} = ac^2$$

where $i = 1, 2, \cdots a$ and c^2 is an arbitrary mean variance chosen by the investigator.

Now $$\sum_{i=1}^{a} S^2_{r_i} = \sum_{i=1}^{a} \frac{2(1-r_i)^2[1+r_i(k-1)]^2}{(k-1)n} = ac^2.$$

Hence

$$n = \frac{2}{ac^2(k-1)} \sum_{i=1}^{a} (1-r_i)^2[1+r_i(k-1)]^2$$

and

$$n'_o = \frac{2}{ac^2(k'_o-1)} \sum_{i=1}^{a} (1-r_i)^2[1+r_i(k'_o-1)]^2$$

Summary

Factors influencing the efficiency and accuracy of heritability estimates based on paternal half-sib correlations have been examined. It is concluded that, in any one experiment, the number of offspring per sire, k, plays an important role in determining the sizes of the errors of estimate. Optimum values of k, k′, for different heritability levels are presented together with a method for calculating the best k value, k'_o, to use when heritability is estimated for several characteristics. Minimum numbers of offspring necessary for estimating heritability to a given accuracy are also discussed.

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ANTIBIOTIC INJECTIONS AND IMPLANTS IN DAY-OLD LAMBS

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SINCE the report of Jukes *et al.* (1950) that the addition of crystalline antibiotic to the ration of pigs increased growth rate, there has been considerable interest in the possibility of using implants and injected suspensions of antibiotics to increase gains and/or reduce disease losses. Noland *et al.* (1953) were unable to demonstrate a benefit from subcutaneous implants in 2- to 12-day-old pigs with bacitracin, procaine penicillin G, chlortetracycline hydrochloride, and chlortetracycline calcium pellets on 56-day weights. Beeson *et al.* (1954) concluded that the subcutaneous implantation of 2-day-old lambs with antibiotic pellets had no significant effect on growth rate.

Experimental Procedure

In a study to determine the possible value of antibiotics on rate of growth and livability of lambs, 424 grade lambs born from January 20 to March 25, 1953 inclusive, at the Dixon Springs Station were used. The lambs were sired by purebred Suffolk and Hampshire rams and were out of native and western grade ewes. The ewes were taken off pasture December 1, 1952, and housed in closed pole-type sheds with adjacent exercise lots. At that time the ewes were treated for internal parasites with a phenothiazine drench. A roughage ration consisting of a full feed of corn silage and legume hay was fed to the ewes. It was supplemented with a grain ration composed of 2 parts ground ear corn, 2 parts oats, and 1 part soybean oil meal fed at the rate of 0.75 lb. per head per day until lambing at which time it was gradually increased to 1½ lb. per head per day. A mineral mixture of steamed bone meal, feeding limestone, and salt (2:2:1) was always available as well as a plentiful supply of fresh, clean water.

The lambs were divided into 10 lots and given implants or injections of antibiotics at various dosage levels (table 1). As lambs were dropped their navels were treated with tincture of iodine, and the ewe and her offspring were placed in an individual holding pen. Each day the lambs born during the previous twenty-four hours were ear tagged, weighed, lotted, and injected or implanted subcutaneously on the side of their neck. For the first 10 sets of twin lambs the treatment was given to the smaller twin; for the next 10 sets the treatment was given to the larger twin, and so on. This

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procedure equalized the number of large and small lambs in the different groups. The untreated twin in each instance was the paired control. In the case of single lambs every other lamb was treated, and the untreated alternate was the paired control. To equalize the ages of lambs in the lots, the treatment was given from lots 1 to 10 then from lots 10 to 1, and so on.

The ewe and her offspring were then placed in a larger holding pen with a limited number of ewes with lambs of similar age. At 10 days of age lambs were weighed, castrated, and docked. At that time the ewes and lambs were moved to an open pole-type shed with an adjacent exercise lot, and a creep was provided for the lambs. The creep ration consisted of

TABLE 1. INJECTION AND IMPLANT LOTTING OF LAMBS

Lot no.	Treatment	Dosage level
	Injection, 25 mg. per cc.	
1	Oxytetracycline hydrochloride in oil	1 cc.
2	Oxytetracycline hydrochloride in oil	1 cc.
	Implant, mg.	
3	Oxytetracycline hydrochloride implant	25
4	Oxytetracycline hydrochloride implant	50
5	Chlortetracycline calcium implant	20
6	Chlortetracycline calcium implant	60
7	Procaine penicillin G implant	16.7
8	Procaine penicillin G implant	50
9	Bacitracin implant	20
10	Bacitracin implant	60

3 parts ground shelled corn, 3 parts ground oats, 2 parts wheat bran, and 2 parts soybean oil meal with legume hay offered free-choice. All ewes and lambs were placed on pasture April 1, 1953, and weighed off-experiment on June 8, 1953.

Records included birth date and weight, 10-day weight, off-experiment weight, and date and cause of any deaths. Tissue samples from the area of injection and implant were removed from the necks of dead lambs and submitted to the laboratory for histopathological examination.

Results and Discussion

A summary of the weight and gain record of single lambs is presented in table 2. The control groups of lots 5, 7, and 9 had made a greater average gain at the end of the first 10 days (7.3, 7.8, and 7.6 lb., respectively) than the treated groups (5.9, 6.8, and 6.7 lb., respectively). In lot 8 the greater gain was made by the treated group (7.4 lb. compared with 6.4 lb., respectively). In all cases the variations could be attributed to the varient performance of only one lamb.

Table 3 shows the summary of the record for twin lambs. The treated group of lot 4 showed some increase in gain (7.9 lb.) over the untreated group (7.5 lb.), while the reverse was true in lot 5 (5.9 lb. compared with 7.3 lb.). The variation was attributed to the varient performance of but one or two lambs in the specific group.

TABLE 2. SUMMARY OF RECORDS FOR SINGLE LAMBS

Lot no.	Group	Birth weight	To 10-day age		To June 8		
			No. lambs [a]	Gain	No. lambs [a]	Weight	Daily gain
		lb.		lb.		lb.	lb.
1	Treated	10.8		7.3	5	73.4	0.50
	Control	11.1	7 [b]	7.7		75.8	0.52
2	Treated	10.2	8	6.5	6	59.0	0.44
	Control	10.7		6.8		69.0	0.52
3	Treated	12.4	9	7.9	6	81.5	0.58
	Control	10.7		7.3		74.3	0.54
4	Treated	12.9	7	7.9	5	82.8	0.57
	Control	12.1		7.5		86.0	0.60
5	Treated	11.9	9	5.9	7	71.0	0.53
	Control	10.6		7.3		64.7	0.49
6	Treated	11.6		7.4	3	80.0	0.54
	Control	11.8	8 [b]	7.6		82.7	0.57
7	Treated	11.3	11	6.8		68.4	0.51
	Control	12.9		7.8		82.4	0.62
8	Treated	12.3	9	7.4	5	76.6	0.56
	Control	11.6		6.4		68.2	0.49
9	Treated	10.9	8	6.7	5	75.8	0.53
	Control	12.5		7.6		83.8	0.58
10	Treated	11.2	9	6.9	6	78.3	0.55
	Control	11.2		7.5		76.5	0.54
Av.	Treated	11.6		7.1		73.9	0.52
	Control	11.6		7.4		75.9	0.55

[a] The number of lambs was the same in each treated group and its respective control group. When a lamb died in either a control or treated group its mate was removed from the experiment.
[b] One lamb died before 10 days of age.

At the termination of the experiment on June 8, there was no statistically significant difference in average daily gain between treated control either in singles or in twins. Death losses were very low and were not confined to any particular lot. Autopsies showed four single lambs, all of which were in treated lots, died of respiratory infection. In the twin lambs one treated lamb and two controls died of respiratory infections. Among other causes of death were stiff lamb disease, grass tetany, wool ball and overlain.

Temperature and moisture data are shown in table 4. The winter was generally mild, and average or below in moisture. This type of "open winter" was perhaps partially responsible for the low death rate of the lambs.

TABLE 3. SUMMARY OF RECORDS FOR TWIN LAMBS

Lot no.	Group	Birth weight	To 10-day age		To June 8		
			No. lambs[a]	Gain	No. lambs[a]	Weight	Daily gain
		lb.		lb.		lb.	lb.
1	Treated	8.8	18	5.2	14	60.1	0.44
	Control	8.8		5.1		56.9	0.41
2	Treated	9.1	12	5.3	10	61.5	0.44
	Control	9.4		4.8		58.6	0.41
3	Treated	10.1	10[b]	5.2	10	61.6	0.44
	Control	9.8		5.2		60.7	0.44
4	Treated	9.2	12	5.3	9	58.6	0.42
	Control	9.0		3.9		53.0	0.37
5	Treated	9.5	14	5.8	12	54.8	0.38
	Control	9.4		5.4		59.2	0.42
6	Treated	9.7	14	5.5	12	60.9	0.42
	Control	9.2		5.7		61.4	0.43
7	Treated	9.4	11[c]	5.3	10	57.4	0.40
	Control	9.6		5.1		54.1	0.37
8	Treated	9.3	14	5.3	13	59.6	0.43
	Control	10.0		5.4		61.1	0.43
9	Treated	9.3	10[c]	4.8	8	55.5	0.41
	Control	9.8		5.1		59.8	0.44
10	Treated	9.4	12[c]	4.8	9	55.1	0.41
	Control	9.5		5.2		55.2	0.41
Av.	Treated	9.4		5.3		58.7	0.42
	Control	9.4		5.1		58.2	0.41

[a] The number of lambs was the same in each treated group and its respective control group. When a lamb died in either a control or treated group its mate was removed from the experiment.
[b] Two lambs died before 10 days of age.
[c] One lamb died before 10 days of age.

TABLE 4. TEMPERATURE AND PRECIPITATION[a]

Month	Temperature		Precipitation	
	Average	Departure from normal	Average	Departure from normal
	deg.	deg.	in.	in.
January	39.0	+4.8	3.71	−0.81
February	40.3	+5.0	1.41	−1.68
March	49.6	+2.4	6.05	+1.47
April	53.4	+1.9	4.36	−0.10

[a] At the Dixon Springs Experiment Station (Pope County, Illinois). Listed as Glendale Experimental Farm in Weather Bureau Summaries.

Summary

The effect of injecting oxytetracycline HCl in oil and of implanting bacitracin, procaine penicillin G, chlortetracycline calcium, and oxytetracycline HCl on the growth rate and death loss of day-old lambs has been investigated. Various dosage levels were administered subcutaneously on the side of the neck. Twin and single lambs were used with each treated lamb having a paired control.

No significant differences between treated and untreated single or twin lambs were found in 10-day weights, death losses, or off-experiment weights. No damaging effects were observed in the areas of injection or implantation.

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THE EFFECT OF OXYTOCIN ON FERTILITY IN GILTS ARTIFICIALLY INSEMINATED WITH A LOW SPERM CONCENTRATION AND SEMEN VOLUME [1, 2]

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ARTIFICIAL insemination of swine is successful when a comparatively large volume of semen is used (Rodin *et al.*, 1936; Lasley, 1943; Ito *et al.*, 1948; Wiggins *et al.*, 1951; Polge, 1956; Mesnil du Buisson *et al.*, 1956; Aamdal and Hogset, 1957; and Stratman *et al.*, 1958). Most researchers have used 50 ml. or more of fresh semen; however, Wiggins *et al.* (1951) found that 20 ml. of fresh semen diluted to 50 ml. gave satisfactory fertility in gilts, but lower concentrations in this same volume were inferior. A volume of 20 ml. of fresh semen allows a maximum of 10 inseminations per ejaculate (190 ml. of strained semen per ejaculate, unpublished—University of Wisconsin). Thus, it is desirable to reduce the volume of fresh semen needed for each insemination to permit greater use of superior sires.

Oxytocin stimulates the myo-epithelial cells of the bovine mammary gland to contract (Ely and Petersen, 1941) and increases the amplitude and frequency of the contractions of the bovine uterine musculature either *in vivo* or *in vitro* (Van Demark and Hays, 1953, 1955). Oxytocin causes milk "let down" in the sow also. It is reasonable to assume that similar uterine contractions would occur in the sow. Van Demark and Moeller (1951) reported that uterine motility in the cow would transport non-motile sperm to the ovarian portion of the oviduct in 4.3 minutes.

It was reasoned that smaller volumes of semen may obtain satisfactory fertility with artificial insemination of swine by increasing uterine motility to facilitate the transportation of sperm. A preliminary study, mostly with one boar and a limited number of gilts, indicated a beneficial effect when an oxytocic substance was administered intrauterine. Therefore an experiment was designed to test further the effects of oxytocin on the fertilization and conception rate in gilts when a small volume of semen and relatively small numbers of sperm were used for insemination.

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Methods and Materials

Three yearling boars (a Chester White, a Landrace-Chester White, and a Landrace-Chester White-Spotted Poland China), maintained in individual pens and self-fed the ration shown in table 1, provided semen for this study. Boars were ejaculated every third day by means of an artificial vagina and a canvas covered dummy sow.

The volume of whole semen was measured immediately after collection and also after straining through 4 layers of 44×36 mesh gauze.

TABLE 1. COMPOSITION OF THE RATION FED *AD LIBITUM* TO BOARS

Ingredient	Pounds
Shelled corn	600
Ground oats	600
Alfalfa meal (17%)	600
Tankage (55%)	100
Soybean oil meal (44%)	100
Trace mineralized salt	2
Chlortetracycline (aureomycin)	10
Zinc sulphate	1
Total	2013

A type and percentage motility rating as previously described (Stratman *et al.*, 1958) was established for each sample. The type rating for motility ranged from 5 to 9 with a mean of 7.5. Percent motile spermatozoa ranged from 60.0 to 95.0% with a mean of 80.1%. Sperm concentration was determined by a hemocytometer after which the volume needed to supply a total of 2.5 billion sperm (both live and dead) was centrifuged for 6 minutes at 1,500 rpm. in a centrifuge with a diameter of 27.5 cm. After centrifugation, the supernatant fluids were decanted and the remaining sperm and seminal fluid were rediluted to a volume of 20 ml. with a whole homogenized milk diluent (Thacker and Almquist, 1951). Dihydrostreptomycin sulfate was added to the diluent at the rate of 1000 mcg. per ml. The diluent and semen were brought to approximately the same temperature before combining. The diluted semen was inseminated within 45 minutes after the dilution was made.

Ninety gilts weighing 180 to 230 lb., of mixed breeding and of unknown sexual age (number of pre-experimental estrous cycles unknown) were obtained from a local stockyard for this study. Only gilts that appeared to be healthy and in good physical condition were used.

The gilts were checked at 24-hour intervals with a vasectomized boar for estrus and were considered to be in heat when they would allow the boar to mount. Natural mating was not permitted. The gilts were inseminated within 4 hours after estrus was detected.

The sequence in which the gilts exhibited estrus determined the order in which they were assigned to the experiment. Three gilts exhibiting heat at the same heat check were assigned as a group. Within each group of three gilts, assignment to a specific treatment was at random and all gilts within each group were bred from the same ejaculate. The collection schedule was rotated among the three boars so that each boar was collected every third day. Gilts were bred to the boar scheduled for collection on the day the gilts were assigned to the experiment.

One gilt in each group of three was designated as a control (C) and inseminated with 2.5 billion sperm suspended in 20 ml. of diluent. A second gilt (S) was inseminated in the same manner as the control gilt, but 10 I.U. of oxytocin (Pitocin, Parke-Davis) was added to the semen

TABLE 2. NUMBER AND DISTRIBUTION OF GILTS ELIMINATED FROM THE STATISTICAL ANALYSIS

Reason for elimination	Number of gilts
Ova recovery of less than 50%	7
Abnormal reproductive tract	4
Gilts lost during slaughter	4
Other	2
Total number eliminated	17
Total number used for statistical analysis	73
Total number in experiment	90

sample immediately prior to the insemination (preliminary studies indicated there was no noticeable effect of the oxytocin carrier on sperm survival). The third gilt (I) was inseminated in the same manner as the control gilt, but 10 I.U. of oxytocin was injected into the ear vein within 5 minutes after insemination.

All gilts were slaughtered 12 to 48 hours after the end of estrus. The reproductive tract was recovered and flushed with 0.9% saline solution to recover the ova, which were examined under a steroscopic microscope to determine fertility.

Percent fertility is expressed as the percentage of the ova recovered that showed normal cleavage. Percent conception is expressed as the percentage of the gilts that had one or more fertile ova at slaughter. Litter size is expressed as the number of fertile ova recovered at slaughter. Gilts were eliminated from the study if they had gross abnormalities of the reproductive tract, if less than 50% of the ova were recovered, and if more than one of the group of three were eliminated. Seventeen gilts were eliminated; the causes and distribution are shown in table 2.

Since percentages are not normally distributed, they should not be analyzed by the usual analysis of variance. An angular transformation

was made as outlined by Snedecor (1953) and these transformed values were examined statistically as outlined by Snedecor (1953) and Kramer (1956).

Results and Discussion

The percent fertility is shown in table 3. An analysis of variance indicated a difference among the three treatment groups ($P<0.01$) and among the three boars ($P<0.05$). The interaction of boar and treatment was not significant. The mean fertility (table 3) for the control (C), semen (S), and intravenous (I) groups was 58.3%, 44.7%, and 71.5%, respectively, while the mean fertility was 45.1%, 60.8%, and 68.5% for boars 114, 87x, and 382, respectively.

The application of the multiple range test (Kramer, 1956) to the percent of fertile ova by boar and by treatment group is illustrated in table 4 and indicates that only the 71.5% fertile ova for the intravenous treated group (I) differs from the 44.7% fertile ova of the semen treated group (S) ($P<0.01$). The 68.5% fertile ova for boar 382 differed only from the 45.1% fertile ova for boar 114 ($P<0.05$).

Further examination of the means in table 3 indicates that within boars the oxytocin-intravenous groups (I) either equalled (boar 382) or was higher (boars 87x and 114) in fertility than the semen treated (S) or the control (C) group and mean litter size at 3 days for each boar was larger in the intravenous treated group than either the semen treated or the control group.

The mean litter size at slaughter for gilts bred to boars 87x, 114 and 382 was 5.6, 4.7 and 7.1 cleaved eggs, respectively and did not differ significantly ($P<0.10$). The control (C), semen (S), and intravenous (I) groups had 5.6, 5.0 and 6.8 cleaving eggs, respectively. Three-day litter size as expressed in this report is a combination of ovulation rate, fertilization rate, and ova recovery rate. No significant difference existed among the treatment groups for ovulation rate or recovery rate; therefore, most of the difference in litter size among the treatment groups can be attributed to the differences in fertilization rate.

The recovery rate of 81.8% compares favorably with other reports (Hauser *et al.*, 1952, 78.9%; Squires *et al.*, 1952, 80.3%; Baker *et al.*, 1954, 80.6%; and Stratman *et al.*, 1958, 78.1%).

There was a significant difference in ova recovery rate among boars ($P<0.01$). It is not readily apparent why there was a boar effect on percent of ova recovered, especially in view of the fact that most of the seminal fluids were poured off following centrifugation, and a standard diluent used to obtain the desired volume.

Intravenous injections of gilts with oxytocin indicated a beneficial effect on percent fertility for two boars and on litter size for all boars when 2.5 billion sperm suspended in 20 ml. was inseminated. Addition of oxytocin to the semen had a detrimental but nonsignificant effect on the

TABLE 3. PERCENT FERTILITY, CONCEPTION, AND OVA RECOVERED AND LITTER SIZE AT 3 DAYS GESTATION BY BOAR-TREATMENT GROUPS

Boar no.	Treatment group	Number of gilts	Percent fertile ova					Percent conception	Percent ova recovered	Litter size at slaughter
			0	1–49	50–99	100	Average			
87x	(C) Control [a]	9	1 [d]	3	4	1	56.8	88.9	75.9	5.7
	(S) Semen [b]	9	–	6	3	–	43.6	100.0	86.2	4.7
	(I) Ear injection [c]	8	–	1	3	4	82.1	100.0	70.9	6.5
114	(C) Control	8	1	4	2	1	48.0	87.5	85.5	4.3
	(S) Semen	7	3	2	2	–	24.7	57.1	90.8	3.3
	(I) Ear injection	8	1	1	5	1	62.6	87.5	81.0	6.4
382	(C) Control	8	–	1	5	2	70.0	100.0	82.1	6.8
	(S) Semen	8	–	2	5	1	65.8	100.0	75.4	7.0
	(I) Ear injection	8	–	2	3	3	69.8	100.0	86.2	7.5
All boars	(C) Control	25	2	8	11	4	58.3	92.1	81.8	5.6
	(S) Semen	24	3	10	10	1	44.7	85.7	84.1	5.0
	(I) Ear injection	24	1	4	11	8	71.5	95.8	79.4	6.8
Total or average		73	6	22	32	13	58.2	91.2	81.8	5.8

[a] Each gilt received 20 ml. of diluent containing 2.5 billion sperm.
[b] Same as control except 10 I.U. of oxytocin was added to the semen sample.
[c] Same as control except 10 I.U. of oxytocin was injected intravenously.
[d] No. gilts in each percent fertile ova subgroup.

average litter size and on the average percent fertile ova. Oxytocin injected intravenously was of more benefit in increasing the percent fertility and consequently the litter size in boars 87x and 114 than in boar 382.

TABLE 4. RESULTS OF MULTIPLE RANGE ANALYSIS APPLIED TO PERCENT FERTILITY BY BOAR AND BY TREATMENT GROUPS [a, b]

Boar no.	114	87x	382
No. gilts	23	26	24
% fertile ova	45.1	60.8	68.5

Treatment [c]	S	C	I
No. gilts	24	25	24
% fertile ova	44.7	58.3	71.5

[a] Values underscored by the same solid line do not differ at the 0.01 level.
[b] Values underscored by the same dotted line do not differ at the 0.05 level.
[c] C=Control group; S=oxytocin semen group; and I=Intravenous oxytocin group.

Summary

Seventy-three gilts artificially inseminated with 2.5 billion sperm suspended in 20 ml. of diluent were assigned to either a control group, a group receiving 10 I.U. of oxytocin intrauterine, or a group receiving 10 I.U. of oxytocin intravenously. The percent of ova recovered that were fertilized, and the percent of gilts conceiving was obtained by boar-treatment group. There was a significant difference among treatments ($P<0.01$) and among boars ($P<0.05$) in percent fertility, but the boar-treatment interaction was not significant. The litter size at 3 days post-breeding was 5.6 for the control group, 5.0 for the group receiving oxytocin intrauterine and 6.8 for the group receiving oxytocin intravenously. There was no significant difference among these groups in three-day litter size.

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SELECTIVE GRAZING BY SHEEP AS SHOWN BY A COMPARISON OF THE CHEMICAL COMPOSITION OF RANGE AND PASTURE FORAGE OBTAINED BY HAND CLIPPING AND THAT COLLECTED BY ESOPHAGEAL-FISTULATED SHEEP

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THE problem of obtaining a sample of forage which truly represents that selected by the grazing animal has long vexed researchers in their attempts to evaluate pasture and range feed. Harris *et al.* (1952) have reviewed the problems involved in range nutrition studies. Cook *et al.* (1958) state that hand plucking is totally inadequate on complex mixtures of plant species. Hardison *et al.* (1954) have reviewed the subject of selective grazing and obtained some quantitative measure of the difference between the forage available and that grazed. They ran concurrent digestion trials on steers grazing pasture and stall-confined steers fed soilage from a similar area. On the basis of these investigations they concluded that the chemical composition of clipped herbage is an unreliable index of the chemical composition of the forage selected by the animal. Meyer *et al.* (1957) studied selective grazing of both steers and lambs by comparing the digestibility of forage fed as soilage and grazed as pasture. They found differences in total digestible nutrients (TDN) and gain per pound of TDN in favor of the grazed forage. Their data also indicate that sheep graze more selectively than cattle.

In the present paper the chemical composition of forage obtained by hand clipping and by esophageal-fistulated sheep is presented as quantitative evidence of the selection practiced by grazing sheep.

Experimental

Six grade Corriedale wethers were fitted with esophageal fistulas by the technique described by Torell (1954). Various combinations of these wethers were used to collect samples of the forage to be analyzed. As more than one collection per wether per pasture has been shown to introduce heterogeneous variability into the data, analyses of only first collections for each sheep have been used in this study (Weir *et al.*, 1958). While the wethers were collecting esophageal samples, hand-clipped samples of the forage were obtained by clipping square-foot plots randomly located in the grazing area. A minimum of three plots were clipped on irrigated pasture and 18 on the Hopland ranges or pasture.

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During 1955, 1956 and early 1957, 49 hand-clipped samples and 111 individual sheep esophageal-fistula collections were made on a wide variety of range and pasture conditions at various seasons of the year. At the Hopland Field Station, located in southeastern Mendocino County in the North Coast section of California, studies were made on two types

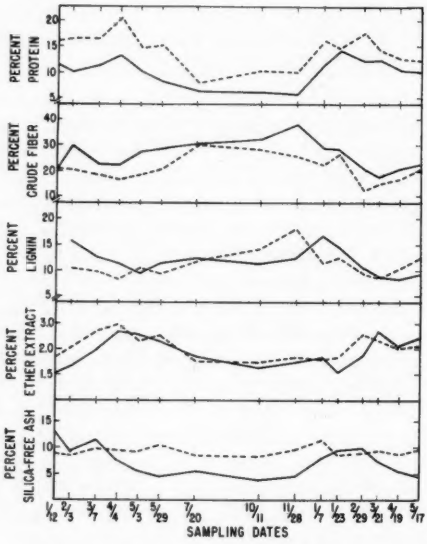

Figure 1. The composition on a dry matter basis of forage collected by esophageal-fistulated sheep and by hand clipping on ungrazed, annual, native range at the Hopland Field Station from January 12, 1955 to May 17, 1956. Broken line is for esophageal-fistula samples and solid line for handclipped samples.

of vegetation. The native range consists of a wide variety of annual grasses, legumes and broadleaf herbs. The vegetation has been described in detail by Heady (1956). In 1955, an ungrazed area of this range was sampled on nine different dates. In 1956, a similar area was sampled on eight different dates prior to grazing by the Station flock of sheep. This area was sampled on four dates after being grazed by the large group of sheep. Another series of collections was made at Hopland on pastures developed from old grain fields by seeding with Harding grass, annual clovers and other desirable species as described by Torell *et al.* (1956).

In 1956, these pastures were sampled 13 times prior to grazing by a large flock and eight times immediately after this grazing. On the Davis Campus, essentially pure stands of Sudan grass, alfalfa, birdsfoot trefoil and Ladino clover pastures were studied. These pastures were sampled seven times for this study.

The esophageal-fistula samples were collected as they dropped from the fistula in plastic bags. The hand-clipped samples were also placed in plastic bags as collected. After drying in a forced air oven, the samples were ground and sub-sampled for chemical analysis. Total nitrogen, crude fiber, ether extract, silica, and ash were determined according to A.O.A.C. methods (1955). Lignin determinations were made by the method of Ellis *et al.* (1946). Crude fiber determinations were not made on samples collected at Davis nor was silica-free ash determined on two samples collected in 1955 at Davis.

For comparative purposes the composition of the hand-clipped samples was plotted with the mean composition of all esophageal-fistula samples collected at the same time and place. Figure 1 shows these results for the ungrazed, native range samples collected in 1955 and 1956 at Hopland. Plotting the data for the other pasture types showed a similar pattern. On all occasions on all pastures, the protein content of the esophageal sample was higher than that of the corresponding hand-clipped sample. The crude fiber content of the hand-clipped sample was always higher than that of the esophageal sample on pastures that were ungrazed; however, when the pasture or range had been grazed by other sheep, the difference was smaller and on a few occasions the esophageal-fistula sample contained more crude fiber than the hand-clipped sample. As shown in figure 1, no consistent difference in the lignin content of the two types of samples could be detected. Crossing lines were obtained for all types of pasture both grazed and ungrazed. This is surprising in view of the consistent pattern obtained with crude fiber. This erratic behavior of the lignin content of the samples is not attributed to laboratory procedures, as our laboratory has made many lignin analyses with excellent checks on duplicate determinations. Plotting the composition of the samples for ether extract also showed no consistent difference with crossing lines occurring on all types of pasture. For silica-free ash the trend appears to be for the esophageal-fistula samples to contain more ash than the hand-clipped samples but this relationship is not constant. The mineral content in the saliva undoubtedly contributes to this difference. Lofgreen (1958) has shown that the saliva is particularly rich in phosphorus.

For statistical analyses of the relationship between the hand-clipped samples and the esophageal samples, each component of the hand-clipped sample was paired with the comparable component of the individual esophageal-fistula collected samples. The difference between the hand-clipped and esophageal samples from each type of pasture irrespective of season was analyzed by the "t" test with a correction made for the

TABLE 1. MEAN VALUES AND DIFFERENCES IN CHEMICAL COMPOSITION OF FORAGE SAMPLES COLLECTED BY HAND CLIPPING AND BY THE ESOPHAGEAL FISTULA ON VARIOUS PASTURES AND RANGES WHICH WERE GRAZED AND UNGRAZED

Items	Ungrazed					Grazed		
	Native range 1955 Hopland	Native range 1956 Hopland	Improved pastures 1956 Hopland	Irrigated pastures Davis	Ungrazed pooled difference	Native range 1956 Hopland	Improved pastures 1956 Hopland	Grazed pooled difference
Number of collections								
Hand clipped	9	9	13	7	38	4	8	12
Esophageal	19	17	26	22	84	10	17	27
				Protein—%				
Esophageal collection	14.5	14.8	22.3	26.7		15.2	20.8	
Hand-clipped collection	9.5	12.2	18.3	21.4		13.0	16.4	
Difference	5.0**	2.6**	4.0**	5.3**	4.1[a]**	2.2*	4.4**	3.0
Standard error					(0.55)[d]			(1.1)
				Crude Fiber—%				
Esophageal collection	22.0	21.0	16.2	—		18.8	17.9	
Hand-clipped collection	27.9	23.5	19.8	—		19.6	18.9	
Difference	−5.9**	−2.5**	−3.6**		−3.5[a, b]**	−0.8	−1.0	−0.9[b]
Standard error					(0.29)			(0.44)

				Lignin—%				
Esophageal collection	11.4	10.6	8.8	5.1		11.8	9.9	
Hand-clipped collection	12.1	11.1	8.0	6.1		10.6	8.0	
Difference	−0.7	−0.5	0.8	−1.0	−0.41[c]	−1.2	−1.9	1.53[c]
Standard error					(0.30)			(0.58)
				Ether Extract—%				
Esophageal collection	2.1	2.1	2.5	2.5		1.9	2.5	
Hand-clipped collection	1.8	1.9	2.6	2.4		2.0	2.8	
Difference	0.3**	0.2	−0.1	0.1	0.16[c]	−0.1	−0.3	−0.21[c]
Standard error					(0.05)			(0.10)
				Silica-Free Ash—%				
Esophageal collection	9.3	9.4	10.0	12.0		10.7	11.8	
Hand-clipped collection	7.4	7.7	9.1	9.2		7.9	8.8	
Difference	1.9*	1.7*	0.9	2.8**	2.2[a]	2.8**	3.0**	2.8
Standard error					(0.28)			(0.53)

* Significant $P<.05$.
** Significant $P<.01$.
[a] V.S. difference between esophageal collection and hand-clipped.
[b] Significant $P<.01$ difference between grazed and ungrazed.
[c] Significant $P<.05$ difference between grazed and ungrazed.
[d] Standard error of the difference in parenthesis.

correlation between paired samples (Goulden, 1952). The results for the various types of pastures are shown in table 1. The protein content of the esophageal samples was very significantly higher ($P<.01$) on all pastures that had not been previously grazed. On those previously grazed the differences were very significant in one case and significant ($P<.05$) on the other pasture. The crude fiber content of the esophageal samples was very significantly lower on all pastures that had not been grazed, but, for pastures which had been grazed, the differences were not significant. The differences between the esophageal samples and the handclipped samples for lignin and ether extract were not significant. The silica-free ash

TABLE 2. CORRELATION COEFFICIENTS BETWEEN CHEMICAL COMPONENTS OF FORAGE SAMPLES COLLECTED BY HAND CLIPPING AND BY THE ESOPHAGEAL FISTULA ON VARIOUS PASTURES AND RANGES WHICH WERE GRAZED AND UNGRAZED

	Ungrazed				Grazed	
Items	Native range 1955 Hopland	Native range 1956 Hopland	Improved pastures 1956 Hopland	Irrigated pastures Davis	Native range 1956 Hopland	Improved pastures 1956 Hopland
Protein	0.85**	0.36	0.76**	0.88**	0.54	0.52
Crude fiber	0.68**	0.88**	0.55*	—	0.90	0.81**
Lignin	0.02	0.45	0.27	0.14	0.19	—0.14
Ether extract	0.74*	0.52	0.75**	0.86*	0.08	0.43
Silica-free ash	—0.04	—0.22	0.30	0.13	0.17	0.15

* Significant $P<.05$.
** Significant $P<.01$.

content of the esophageal samples was significantly higher in three out of four cases when the pastures had not been grazed (one case, $P<.01$, and two cases, $P<.05$) and very significantly higher ($P<.01$) on both pastures that had been previously grazed.

To obtain a pooled estimate of the differences for all pastures a weighting factor of the reciprocal of the standard error of the difference was used. These pooled differences with their standard errors are shown in columns 5 and 8 of table 1. The differences in protein, crude fiber and silica-free ash content of the samples from the ungrazed pastures were very significant. The pooled differences for the grazed versus the ungrazed areas were also tested for significance. For protein and silica-free ash the difference in composition of the samples obtained from the grazed and ungrazed areas was not significant, but for crude fiber the difference between the hand-clipped samples and the esophageal samples was very significantly larger ($P<.01$) when the pastures had not been previously grazed. The pooled differences for grazed and ungrazed forage were significantly different ($P<.05$) for both lignin and ether extract. This

finding is of questionable importance in that the values obtained by hand clipping and by the esophageal fistula were not significantly different.

The correlation between the composition of the hand-clipped samples and corresponding esophageal samples was determined and is reported in table 2. Although some of the correlation coefficients for protein, crude fiber and ether extract were significant, it was not a constant relationship. The low correlation coefficient for lignin and silica-free ash indicate the lack of relation between these components in the two kinds of samples. Analyses of the regression of the composition of the esophageal-fistula samples on the composition of the hand-clipped samples showed that the regressions were so heterogeneous between pastures and varied as to significance to the extent that it does not appear practical to attempt to predict the composition of esophageal-fistula samples from hand-clipped samples by a regression technique.

Discussion

The higher protein content and the lower crude fiber content of the forage collected by esophageal-fistulated sheep compared to that obtained by hand-clipping give an indication of the degree of selection practiced by grazing sheep. Although a small amount of nitrogen is contained in the saliva, earlier tests conducted here (Bath *et al.*, 1956) indicate this has little, if any, effect on the protein content of the ingested feed. Somers (1958) has found the salivary nitrogen production of the sheep as 0.5 to 1.0 gm. per 24-hour period. McDougall (1948) reported that sheep saliva contained about 20 mg. of nitrogen per 100 ml. of parotid saliva and that a single gland excreted from 930 to 1840 ml. in 24 hours. If 1500 ml. of saliva were secreted by each gland per 24 hours, 0.6 mg. of nitrogen would be produced. Assuming a collection period of 30 minutes, the saliva would contribute only 1/48 of daily excretion or at the 1.0-gm. daily level the saliva would furnish about 21 mg. of nitrogen per sample. If the collection contained 200 gm. of dry matter the 21 mg. of nitrogen multiplied by 6.25 (131 mg. protein) would only raise the protein by less than 0.01%.

The smaller difference in crude fiber between the hand-clipped and esophageal collections when the forage had been grazed probably reflects the reduced opportunity for selection by the sheep. The degree of previous grazing undoubtedly would influence the differences in composition found in the forage selected by the two methods.

The procedure used in summarizing the data to obtain a pooled estimate of the differences in composition of the forage samples collected by the two methods does not take into account seasonal changes in the chemical composition of the forage. All of the data were plotted in a manner similar to that shown in figure 1, but no seasonal effect on differences in composition could be detected.

The low correlations obtained for lignin and silica-free ash emphasize

the unpredictability in the composition of forage obtained by the two methods in regard to these components. The variability on different pastures in the relationship of such components as protein appears to preclude the use of regression techniques to predict the composition of what a sheep actually consumes from the composition of hand-clipped forage.

Summary

Selective grazing by sheep was studied by comparing the chemical composition of forage samples obtained by hand-clipping and by esophageal-fistulated sheep on a wide variety of range and pasture conditions at various seasons of the year. The sheep consistently selected forage higher in protein and lower in crude fiber than that obtained by hand-clipping. No consistent differences in lignin or ether extract content were obtained. The silica-free ash content of the forage collected by the fistulated sheep tended to be higher than that of the hand-clipped forage. At least part of this difference must be attributed to the ash content of the saliva.

Pooling all data for ungrazed forage indicated that fistulated sheep selected forage containing 4.1% ($\pm$0.55) more protein and 3.5% ($\pm$0.29) less crude fiber than found in hand-clipped forage. When the forage had previously been grazed by a large flock of sheep the differences were somewhat smaller—3.0% ($\pm$1.1) for protein and 0.90% ($\pm$0.44) for crude fiber. The difference for crude fiber between grazed and ungrazed forage was highly significant.

Correlation and regression studies indicated it was not feasible to estimate what a sheep would eat from hand-clipped material.

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A METHOD FOR PRESERVING WET FECES WITHOUT NITROGEN OR ENERGY LOSS

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VARIOUS investigators (Colovos *et al.*, 1957; Cuthbertson and Turnbull, 1934; French, 1930; Gallup and Hobbs, 1944; Kleiber *et al.*, 1936) have reported losses of nitrogen when feces were dried. In order to prevent these losses, it is a common practice in many laboratories to determine nitrogen on the fresh wet feces. A number of studies have also been made to determine if treating the feces prior to drying may reduce nitrogen loss. Gallup and Hobbs (1944) found that the addition of 25 ml. of 20% acid alcohol reduced the loss of nitrogen but that this treatment interfered with the subsequent determination of fat and crude fiber. French (1930) observed that copper sulphate, formaldehyde, or zinc sulphate reduced the loss of nitrogen from a mixture of feces and urine to a negligible amount. To prevent loss of nitrogen, Peters and Van Slyke (1932) proposed that an aliquot of the daily production of feces be added to sulphuric acid. At the end of the digestion trial period, nitrogen could be determined on this slurry. This method has the disadvantages of requiring daily dry matter determinations to determine the amount of dry feces in the sulphuric acid, and the sampling is difficult. Feces from cattle being fed high roughage rations contain undigested stems of hay which makes representative sampling difficult.

Freezing and refrigeration of daily aliquots of feces with or without the addition of a preservative such as thymol or toluene have also been used as methods of storing samples until the end of the collection period for compositing. This may leave both the bacteria and the enzmyes in an active state and result in losses when the feces are thawed and dried.

The extent of these losses may depend upon the drying conditions. Raymond *et al.* (1953) has reported losses in dry matter in feces when low temperatures and an inefficient oven were used to dry the fecal material. Colovos *et al.* (1957) demonstrated that there was an appreciable loss of energy when feces were dried at 65° C. for 48 hours.

Nitrogen determinations have been conducted on the fresh daily fecal samples in this laboratory. This practice requires the time of a laboratory technician to analyze these samples each day during the collection period. The following experiment was undertaken to develop a procedure for storing wet feces without alteration in composition or loss of nitrogen or energy. Samples could then be composited and analyzed at the end of the collection period. Thus the number of analyses required would be reduced and the work load shifted to a more desirable time.

Experimental Procedure

This experiment was conducted in two phases. In the first phase samples of feces were canned, stored, and later analyzed for nitrogen, dry matter, ash, crude fiber, and ether extract. In the second phase the samples were analyzed for gross energy and dry matter. These values were compared with analyses run on fresh samples to determine the effectiveness of canning in the prevention of losses of the various components.

The fecal samples used in the first phase of the experiment were obtained from six cows maintained on an alfalfa hay-grain ration. Grain-hay ratios varied from 1:1 to 1:10. Grab samples were taken at 2 p.m. and between 5 a.m. and 6 a.m., the afternoon samples being stored in a refrigerator at O° C until the next morning. The two defecations were then mixed and samples taken for each individual cow. Kjeldahl nitrogen was run in triplicate on the fresh materials. Duplicate 400-gm. samples from each cow were dried in a large forced-air dryer at 80° C. At the end of the 5-day collection period the daily samples were composited for each animal and the proximate analyses of these samples were used as the controls.

At the same time the above samples were taken, duplicate 400-gm. samples of fresh feces were also canned. The process involved weighing the feces into No. 2 R-enamel lined tin cans, placing the cans in a boiling water bath for 5 minutes to expel the air from the feces, sealing with a household automatic can sealer and autoclaving for one hour at 10 lb. pressure. They were then cooled and stored at room temperature until the end of the 5-day collection period, when they were opened, composited for each cow and thoroughly mixed with a household electric mixer. Nitrogen was determined on the wet feces and a 400-gm. sample was dried in the sample dryer at 80° C. This material was ground in a Wiley mill, 1 mm. mesh, and analyzed for ash, crude fiber, and fat for comparison with the control samples.

In the second phase of the experiment fecal samples were collected once daily from three dry Jersey cows which were on a conventional total collection digestion trial involving a 3×3 Latin square design. The ration consisted of three lots of orchardgrass hay and each collection period was for 5 consecutive days. Urine and feces were separated by means of a rotating belt device.

Samples were taken from each day's fecal collection of each cow and treated in the following ways: (a) Analyzed immediately, (b) canned and autoclaved. The feces were canned immediately and were stored for varying periods of time up to 6 months at room temperature until opened for analysis. Gross energy determinations were made with an oxygen bomb calorimeter by a modification of the technique of Colovos *et al.* (1957). Combustion of moist samples (1.5 to 2.5 gm., including fresh

and canned feces), was facilitated by the addition of 2 ml. of 95% ethanol as a primer. The alcohol was maintained at 44–46° F. to reduce evaporative loss during addition and mixing with the sample. Pyrex glass rods 3 cm. × 2 mm. were used to mix the feces and alcohol immediately before the bomb was sealed. The gross energy of the alcohol (5,235 cal./ml.) was subtracted from the total gross energy value to obtain the caloric value of the feces. All values were calculated on a dry matter basis for comparative purposes.

Results and Discussion

The results of the first phase are shown in table 1. Each value represents the average of four determinations. The protein content of the canned feces agreed closely with the average of the daily protein deter-

TABLE 1. A COMPARISON OF THE COMPOSITION OF THE DRY MATTER OF CANNED FECES AND FECES HANDLED IN THE USUAL MANNER

	Ash		Crude fiber		Fat		Protein	
Cow no.	Canned	Control	Canned	Control	Canned	Control	Canned	Control
287	14.83	14.38	33.99	34.87	4.36	4.41	14.54	14.19
638	16.14	15.47	35.93	37.07	4.40	4.36	13.69	13.13
697	14.07	14.15	36.91	36.81	4.10	4.25	13.66	13.96
698	14.13	14.08	36.99	36.84	4.64	4.65	13.37	13.36
831	14.20	14.11	34.98	34.79	4.66	4.39	14.78	14.76
1017	16.94	16.78	35.71	35.38	4.57	4.25	14.03	13.94
Ave.	15.05	14.83	35.75	35.96	4.46	4.39	14.01	13.89

minations. There was also close agreement in the other components of the dry matter of the feces, and an analysis of variance of these data revealed that there was no significant difference between canned and the control feces. These results indicate that canning was an effective means of storing feces for future analysis without the loss of nitrogen, ash, crude fiber, or ether extract.

Table 2 summarizes the results of the second phase. The values for period 1 have been omitted because of incomplete combustion of several of the first samples resulting from failure to add enough alcohol and insufficient mixing. No difficulties in combustion of moist samples were encountered after the first week. The caloric value was 5063 ± 133 cal./gm. dry matter (DM) for fresh feces and 5090 ± 96 cal./gm. DM for the canned feces. A comparison of the percent dry matter of the canned and fresh feces indicated that there was no change in dry matter due to canning. The average percent dry matter of the fresh material was 14.82, while the dry matter content of the canned feces was 14.83%. Thus canning prevented any apparent loss of energy during storage.

Canning as a means of preservation and storage of feces for future analysis offers a number of advantages. The number of analyses required

may be reduced because the necessity of daily nitrogen and dry matter determinations is eliminated by compositing the canned materials at the end of the experiment. Dry matter digestibility studies by the ratio technique involve analyses of indicators, and many of these analyses may be conducted on wet feces. Samples may be stored for extended periods of time at room temperature, thus making it possible to shift the analytical work load to a more suitable time for the analyst. The

TABLE 2. DRY MATTER AND GROSS ENERGY VALUES OF BOVINE FECES PREPARED AND STORED BY DIFFERENT METHODS [a]

Cow no.	Period and day no.	Percent dry matter (Vacuum oven 100 °C.)		Calories/gram of dry matter	
		Fresh	Canned	Fresh	Canned
348	II—1	12.51	12.66	5183	5049
	II—2	14.27	14.19	5260	5103
	II—3	13.94	13.93	5255	4901
	II—4	14.20	14.29	5152	4778
	II—5	15.62	15.67	5098	5096
681	II—1	14.78	14.70	5210	4992
	II—2	15.06	15.04	5179	5193
	II—3	14.74	14.72	5001	4946
	II—4	14.64	14.73	5064	5048
	II—5	14.89	15.05	5121	5047
682	II—1	12.83	12.85	5126	5246
	II—2	14.29	14.28	5236	5116
	II—3	14.45	14.41	4778	4822
	II—4	13.96	14.04	5059	4984
	II—5	14.02	14.04	5088	5010
348	III—1	16.93	16.99	5411	5234
	III—2	15.65	15.67	5001	5204
	III—3	14.65	14.58	5032	5058
	III—4	14.77	14.69	4795	5096
	III—5	14.93	14.84	5068	5122
681	III—1	15.37	13.38	5286	5062
	III—2	15.55	15.61	5058	5236
	III—3	15.80	15.87	4917	5265
	III—4	15.72	15.49	4751	5182
	III—5	15.81	15.83	5023	5146
682	III—1	15.04	15.06	5062	5085
	III—2	14.99	15.13	5047	5129
	III—3	15.08	15.16	4774	5317
	III—4	15.62	15.40	4837	5317
	III—5	14.58	14.65	5009	5066
	Average	14.82	14.83	5063	5090
	St. Dev.			133	96

[a] Each value is the average of two analyses.

labor involved in canning feces is small, and valuable refrigerator and freezer space is spared.

Summary

A method of preserving wet feces without loss of nitrogen or gross energy has been described. Samples of bovine feces were canned, stored at room temperature and analyzed for gross energy, nitrogen, ash, crude fiber, ether extract and dry matter. There was no significant difference between these values and those obtained when samples of the same feces were analyzed in the conventional way. Canning of feces proved to be an efficient, simple means of preserving fecal samples.

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THE INFLUENCE OF CERTAIN PHYSICAL PROPERTIES OF PURIFIED CELLULOSES AND FORAGE CELLULOSES ON THEIR DIGESTIBILITY BY RUMEN MICROORGANISMS *IN VITRO* [1, 2]

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THE nutritional value of forages is controlled by a number of physical and chemical factors inherent to the plants used for hay and pasture production. A common illustration of this relationship is the decrease in the digestibility of cellulose or crude fiber in maturing forages associated with the increase in lignin content of these forages. Evidence presented by Quicke *et al.* (1959) suggests that in addition to lignin content there are other changes which affect cellulose availability and digestibility. Cellulose digestion *in vitro* appeared to be proportional to changes in the lignin content during the earlier growth phases of the plant, but as the plant matured, the decrease in digestibility was more rapid than the change in lignin content. This observation suggests the need for studies on forage cellulose and its physical state in the plant cell wall as related to cellulose digestion by rumen micro-organisms. A logical approach was to investigate the effect of some known physical properties of purified celluloses on their digestion by rumen micro-organisms *in vitro*.

Cellulose is composed of both crystalline and amorphous structures since some, but not all, cellulose molecules are oriented in regular crystal-like patterns. Siu (1951) reports that the degree of crystallinity of cellulose affects the rate of its decomposition by cellulolytic organisms or cellulase preparation—the greater the degree of crystallinity, the slower the rate of microbial cellulose degradation. Likewise, the average size of the glucose chains or sub-units making up the cellulose polysaccharide influences the chemical behavior of celluloses.

The results of studies on the relationship of the X-ray patterns, degree of polymerization, and particle size of purified celluloses to their digestibility

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by rumen microorganisms *in vitro* are described herein. Studies on the X-ray diffraction patterns obtained with holocelluloses isolated from forages of varying degrees of digestibility, and with the untreated forages themselves, are also reported.

Experimental

The *in vitro* rumen fermentations were carried out by the procedures described by Bentley *et al.* (1955) with the following exceptions: (1) 50 ml. or one-half of the amount of the reaction mixture was used and (2) the inoculum was prepared as described by Dehority *et al.* (1957). Cellulose was determined on the original samples and on the residue remaining in the

TABLE 1. CELLULOSE DIGESTION, DEGREE OF POLYMERIZATION AND HEIGHT-WIDTH RATIO OF THE MAIN X-RAY PEAKS FOR FOUR PURIFIED WOOD CELLULOSES AND A NATURALLY OCCURRING CELLULOSE, COTTON LINTERS

Sample	Cellulose digested [a]		Degree of polymerization [b]	Height-width ratio [c]
	%	S.E.		
Cotton linters	48.4	0.9	1393	11.5
Wood cellulose:				
SW 40 B	60.5	2.5	773	7.8
BW 40	65.2	1.4	686	7.4
Raybond	69.0	2.0	1080	5.9
SW 40 A	73.8	2.4	973	5.7

[a] Average of seven values with standard errors except SW 40B which is based on three values. One gram of cellulose per flask in 50 ml. of medium. 30 hr. fermentations.
[b] Average of two or three determinations.
[c] Average of three or four determinations.

flasks at the end of a 30-hr. fermentation by the Crampton and Maynard (1938) procedure. The cellulose preparations and hay samples were ground through a 40-mesh screen in a Wiley mill and, where indicated, particles size was determined with a set of standard sieves.[7]

The degree of polymerization was determined by the TAPPI (1950) method based on the viscosity of the cellulose dissolved in cupriethylenediamine, as measured with the falling ball technique. A Bureau of Standards reference oil of known viscosity was used as a standard.

X-ray diffraction patterns were obtained with a diffractometer fitted (Spectron, Ohio X-Ray, Inc.) with a Geiger tube connected to a scaler and a continuous synchronized recorder. The X-ray beam (40 KV and 10 MA) from the copper target was filtered through a nickel filter. The ground samples of four purified celluloses and of cotton linters were pressed onto the

[7] The cellulose samples were kindly supplied by the Hercules Powder Co., Wilmington, Delaware (cotton linters); Rayonier Corp., 161 E. 42nd St., New York (Raybond and other celluloses named in the text); Brown Co., 150 Causeway St., Boston (SW 40A, BW-40, SW 40B); The Northern Utilization Research and Development Branch, Peoria (Sudan Grass Cellulose).

flat surface of the sample holder by means of a mechanical press and X-ray diffraction patterns obtained over the 10° to 30° range. At least three patterns were obtained for each type of cellulose and typical curves are shown in figure 1. Patterns were likewise obtained with chemically untreated forages and holocelluloses prepared from them by the method of Whistler *et al.* (1948).

Results and Discussion

Four purified celluloses having different physical properties; and cotton linters, a native cellulose, were selected for study. The *in vitro* digestibility, the estimated degrees of polymerization and an index based on the X-ray diffraction pattern of each of these celluloses are presented in table 1.

It is apparent that different celluloses are digested at different rates. The same amount of cellulose substrate was used in all experiements and the data are corrected for moisture and ash; thus, one can compare percentage digestion figures directly. Only 48% of the cotton linter cellulose was digested, whereas up to 74% of the cellulose in the SW 40A sample was degraded during the fermentation. Apparently these data reflect the *rate* of microbial cellulose digestion since in experiments continued for 60 hours, 85% or more of the cellulose in all samples, including cotton linters, was digested. Furthermore, chemical treatments employed during the isolation of the purified celluloses did not have an adverse effect on cellulose digestibility—cotton linters *vs.* the four purified celluloses.

A possible explanation for the differences in digestibilities of the celluloses *in vitro* was sought from data on their degree of polymerization (D.P.). The D.P. of a cellulose, in its simplest definition, is an estimate of the average number of glucose units per chain forming a sub-unit of a given cellulose. This estimate gives an indication of the composition of the cellulose, e.g. the predominance of short or long chains would give low or high D.P. estimates, respectively. The results in table 1 do not suggest that a correlation exists between D.P. and the rate of *in vitro* digestion for the limited number of celluloses studied. Cotton linters had the highest D.P. and the lowest rate of digestion; however, the SW 40B cellulose sample with a low D.P. was digested at a rate similar to that of cotton linters.

Cellulose molecules differ in their arrangement. Some are arranged with crystal-like regularity while others are distributed at random; the former are referred to as micelles and the disordered portions are called amorphous regions (Hock, 1952). When X-rays are impinged on cellulose those rays striking the crystalline portion with 3 dimensional regularity, will be diffracted by some definite angle, not as the incident beam, but rather as diffracted beams generating a cone of diffracted rays at this angle $2\ominus$ (Klug and Alexander, 1954). X-Ray diffraction patterns for cotton linters and SW 40A celluloses are shown in figure 1. These curves are typical of cellulose (cf. Hermans and Weidinger, 1948).

X-Ray diffraction patterns have been used to estimate the ratio of crystalline to amorphous material in cellulose, e.g. cotton linters is 70% crystalline (Hermans and Weidinger, 1949). Little difference was observed in the degree of crystallinity of the celluloses examined, but comparison of the patterns obtained with the various celluloses, revealed marked differences between the height-width ratios of the main peaks. This ratio was therefore calculated for the main peak in each of the patterns and this arbitrary index was plotted against the percent *in vitro* digestibility of the

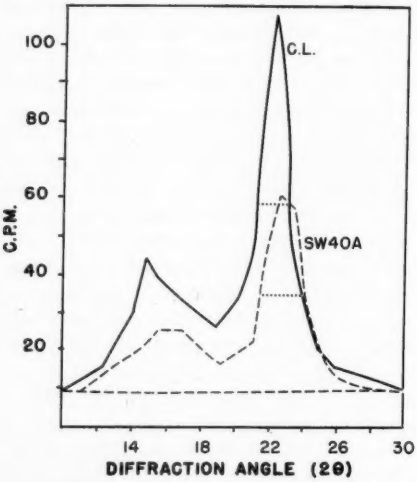

Figure 1. X-ray diffraction patterns for cotton linters (C.L.) and a wood cellulose (SW 40 A) showing the major "peak" on the right. The dotted lines are located at the midpoint of each peak where the width of the curve was taken for the calculation of the "height-width" ratio referred to in the text.

celluloses (see figure 2 and table 1). The broken line shown at the bottom of figure 1 was used as the base for measuring the height of the curve and the width was measured at a point midway between the base and the top of the peak.

The data in table 1 and figure 2 indicate a relationship between this parameter, height/width ratio, and the digestibility of cellulose in the samples studied. A parameter obtained in much the same manner has been used in X-ray diffraction studies in cellulose triacetate (Stroll, 1955). This author suggested that the value obtained was a measurement of crystalline order. It has been suggested by other workers that order distribution or packing perfection in cellulose crystallites may be in closer agreement with accessibility data than is degree of crystallinity (Marchessault and How-

sinon, 1957). Regardless, it would appear that the ratios obtained herein are indicative of a relationship between the susceptibility of the cellulose to microbial attack and the physical characteristics of the cellulose measured by the X-ray diffraction technique employed.

The X-ray patterns for the hays were much lower and the patterns suggested the presence of a greater proportion of amorphous material in the hay cellulose; yet, the general forms of the patterns were similar to those

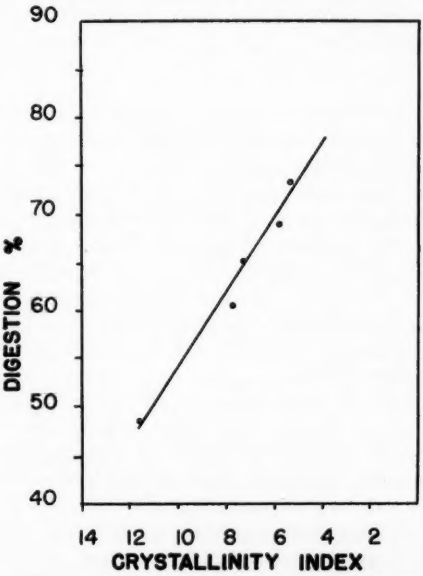

Figure 2. The straight line relationship was obtained when the "height-width" ratio calculated from x-ray diffraction patterns for cotton linters and four samples of wood cellulose, prepared from different sources, were plotted against the percent in vitro digestibility of the different celluloses (cf. table 1).

obtained with purified cellulose. Similar results were obtained with all of the samples, i.e., there were only small differences between the patterns obtained for early-cut timothy (85% digestible cellulose) and late-cut timothy (42% digestible cellulose).

Holocelluloses prepared from mature and immature forages in 1955 and 1956 (Kamstra *et al.*, 1958) and holocellulose isolated from two stages of brome grass in 1957, were also subjected to X-ray diffraction examination. Again no demonstrable differences could be detected between holocelluloses from the early-cut and late-cut alfalfa or between the holocelluloses from the two stages of brome grass. Furthermore, the patterns obtained with

TABLE 2. CELLULOSE COMPOSITION AND DIGESTIBILITY

Sample	α[a]	β[b]	γ[c]	Digestion
	%	%	%	%
Cordenier	96.6	1.4	2.0	57.9
Rayamo	87.5	7.8	4.7	61.4
Hicolor	93.0	2.6	4.4	61.7
Purayonier	96.5	1.9	1.6	64.0
Raybond	88.5	2.0	9.5	74.4

[a] α Cellulose=200 D.P. units.
[b] β Cellulose=10–200 D.P. units.
[c] γ 10 D.P. units.

holocelluloses and the untreated plant materials from which they were isolated, were very similar although the height: width ratio from the former were slightly higher than those from the latter.

Apparently the molecular structures of cellulose in pasture and forage plants is not sufficiently organized to give strong peaks in X-ray patterns. This leads one to the conclusion that much of the cellulose is amorphous. One can then surmise that if physical contact can be made between a forage plant cellulose in its native state and the microorganisms or microbial cellulases, the cellulose should be digestible. This assumption is supported by reports summarized by Siu (1951) on the microbial decomposition of cellulose and cellulose structure.

Another indication of chain length of the sub-units of cellulose is the proportion of α, β, γ cellulose present in a sample. This classification is based on the amount of cellulose soluble in alkali solutions of different strengths. Five samples which differed in respect to the ratio of these components were studied and the results are given in table 2. The digestion obtained in the artificial rumen varied for the different materials but there was no apparent correlation between the amount of α cellulose in the samples and the amount of cellulose digested.

Particle size of cellulose and cellulose-containing feedstuffs may have an influence on cellulose digestibility by the microorganisms (Baker and Harriss, 1947). Since a sample ground to pass a certain screen size contains

TABLE 3. EFFECT OF PARTICLE SIZE ON *IN VITRO* CELLULOSE DIGESTION

Cellulose sample	Particle size, mesh	*In vitro* digestibility, %
Cotton linters	40 < 60	50.7±2.1
Cotton linters	100<150	48.7±0.9
Cotton linters	>200	52.1±2.0
Wood cellulose:		
SW 40 A	40 < 60	70.1±2.5
SW 40 A	100<150	71.2±1.0
SW 40 A	>200	69.3±2.1

particles ranging in size from a powder to particles just small enough to pass through the screen, the possible effect of particle size was investigated using the series of samples shown in table 3. Samples of cotton linters and wood cellulose, SW 40A, ground to pass a 40 mesh screen were sieved and fractions were obtained which would pass through 40–60, 100–150 and 200-mesh sieves. No marked differences were observed in the digestibility of the cellulose in the various fractions. Digestion comparable to that given in table 1 for similar samples was obtained. On the other hand the digestibility of a sample of cotton linters ground to a fine powder in a ball-mill using stones was increased slightly. It was interesting that X-ray studies indicated the presence of silica in the ball-milled material.

Summary

The susceptibility of purified celluloses to attack by rumen microorganisms *in vitro* is influenced by the source or the method of preparation. Cotton linters, a native fiber, which is known to be highly crystalline was digested at a slower rate than samples of isolated wood celluloses. This difference was not due to particle size or to the average mass of the glucose chains making up the fibrils expressed as degree of polymerization.

Examination of the samples with an X-ray diffractometer revealed differences in the height-width ratio of the main peaks of the X-ray patterns. This ratio was found to be correlated with the digestibility of the sample. Indeed, it is suggested that this parameter may be a crude estimation of degree of packing perfection. In any case it would appear that this parameter was indicative of a relationship between the susceptibility of cellulose to microbial digestion and the physical characteristics responsible for the X-ray diffraction patterns obtained. Furthermore, this observation would suggest that the activity of cellulases from rumen organisms are affected by cellulose structure in much the same manner as the cellulases isolated from molds and soil organisms which attack cellulose in cloth or cellulose present in soil residue.

Forages of varying cellulose digestibility *(in vitro)* and isolated forage holocelluloses were examined by the same X-ray procedure. No differences were detected in the X-ray patterns and the results suggested that these celluloses were more amorphous than the purified isolated celluloses. It appears that native celluloses as present in forage plants should be readily digested if contact is made between them and the rumen organisms or microbial cellulases.

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AVAILABILITY OF THE NITROGEN IN SOME AMMONIATED PRODUCTS TO BOVINE RUMEN MICROORGANISMS [1, 2]

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THE economical ammoniation of carbohydrate residues has led to an investigation of its use in the production of protein extenders for ruminants. Early feeding trials with cattle suggested that the nitrogen in certain ammoniated products was utilized for growth (Millar, 1944; Davis *et al.*, 1946; Culberston *et al.*, 1950; McCall and Graham, 1953) and for milk production (Magruder *et al.*, 1951); whereas, unimpressive or negative results were obtained in more recent cattle feeding trials (Barrentine and Darnell, 1954; Richardson *et al.*, 1954; Pope *et al.*, 1955; King *et al.*, 1957; Tillman *et al.*, 1957a). Furthermore, digestion and nitrogen balance trials with sheep (Ferguson and Neave, 1943; Tillman and Swift, 1953; Tillman *et al.*, 1957b) and cattle (Davis *et al.*, 1955; King *et al.*, 1957; Tillman *et al.*, 1957a) and *in vitro* fermentation studies with bovine rumen microorganisms (Davis *et al.*, 1955) have shown that the nitrogen in ammoniated feeds is not as available to rumen microorganisms as the nitrogen from urea or natural protein.

The object of the studies reported herein was to use the artificial rumen technique to obtain estimates of utilization and availability of the nitrogen contained in certain ammoniated products to rumen microorganisms.

Experimental

The *in vitro* fermentation technique previously reported by Bentley *et al.*, (1955) was used. The inocula were obtained from steers fitted with ruminal fistulas and fed either alfalfa or timothy hay. Cellulose was determined by the volumetric method of Hershberger *et al.*, (1955) when purified cellulose and non-cellulose containing nitrogen sources were used. The Crampton-Maynard procedure (1938) for determining cellulose was used when the ammoniated nitrogen source contained cellulose. Ammonia nitrogen was determined by the A.O.A.C. distillation procedure and total nitrogen by the Kjeldahl-Gunning method. The amount of cellulose digested during a 30-hr. fermentation period and/or the in-

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[3] The results presented herein are from a dissertation by T. V. Hershberger submitted to the Graduate School, The Ohio State University, in partial fulfillment of the requirements for the Ph.D. degree in 1955. Present Address: Department of Animal Nutrition, Pennsylvania State University, University Park, Pennsylvania.

[4] Department of Animal Science.

crease in 10% trichloroacetic acid insoluble nitrogen ($\triangle$TCA–N) [5] were used as criteria for estimating the nitrogen availability to rumen microorganisms *in vitro* in the following ammoniated preparations [6]: Ammoniated cane molasses (15% ACM), ammoniated invert cane molasses (33% ACM), ammoniated corn cobs (ACC), ammoniated furfural residue (AFR), ammoniated bagasse, and ammoniated bagasse extract. In addition, primary, secondary and tertiary glucosamine derivatives were tested as sources of nitrogen.

Results and Discussion

Preliminary experiments were performed to determine the response of rumen microorganisms to various levels of available nitrogen. Urea was

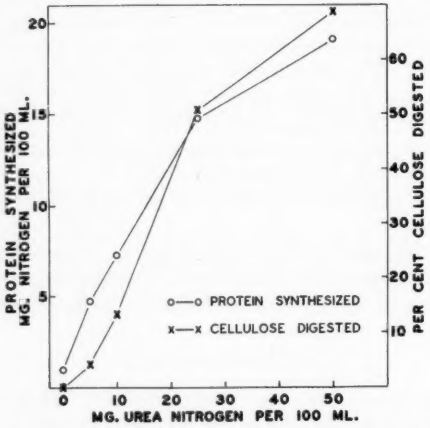

Figure 1. Protein synthesis and cellulose digestion as affected by level of urea nitrogen in the medium.

used as the nitrogen source since it is a normal component of ruminant saliva, is used extensively in ruminant feeds, and is readily converted to ammonia in the rumen. The results in figure 1 show that both cellulose digestion and protein synthesis increased with each increment of added urea and, when the data are plotted, typical growth response curves are obtained. It seemed, therefore, that changes in TCA-N and cellulose digestion during a fermentation should reflect the level of available nitro-

[5] A change in the trichloroacetic acid insoluble nitrogen content of the medium will be referred to as $\triangle$TCA-N and it is interpreted as an estimate of the amount of bacterial protein synthesis.

[6] The ammoniated cane molasses was furnished by the Commercial Solvents Corp., ammoniated corn cobs by Northern Utilization Research and Development Div. U.S.D.A., Peoria, Ill., ammoniated furfural residue by the Quaker Oats Co., Chicago, and the bagasse samples by the Sugar Foundation Inc., New York.

gen in the medium over the range 0 to 50 mg. %. The carbohydrates in the medium were cellulose (1%), glucose (0.1%) and starch (0.5%). When 0.5% starch was removed from the medium, the curve for cellulose digestion remained essentially the same, but protein synthesis did not exceed 8 mg. % nitrogen. Conversely, when more than 0.5% starch was added, the curve for protein synthesis remained essentially the same, but cellulose digestion decreased due to the microorganisms growing more rapidly on starch than on cellulose, thereby utilizing the available nitrogen.

The ammoniated preparations were analyzed, as received, for ammonia nitrogen, trichloroacetic acid (10%), precipitable nitrogen and total nitrogen (table1). The ammonia nitrogen in the preparations varied from a

TABLE 1. PARTITION OF NITROGEN IN UREA AND AMMONIATED PREPARATIONS

Samples	Mg. nitrogen per gram				Protein equivalent, %
	Ammonia	TCA Insol.	Other	Total	
Urea	456.0[a]	0	0	456.0	285.0
Ammon. cane molasses	3.5	2.3	14.6	20.4	12.8
Ammon. invert cane molasses	6.9	1.7	35.5	44.1	27.6
Ammon. furfural residue	26.2	15.9	4.3	46.4	29.0
Ammon. corn cobs	1.3	6.4	14.3	22.0	13.8

[a] Ammonia released after treatment with urease.

low of 5.9% of the total nitrogen for ammoniated corn cobs to a high of 56.4% for ammoniated furfural residue. In testing for available nitrogen in ammoniated molasses, sucrose was added to control flasks in amounts equal to the estimated amount in cane molasses, since soluble carbohydrates have been shown to influence protein synthesis and cellulose digestion (Arias *et al.*, 1951).

The availability of the nitrogen in ammoniated cane molasses (15% ACM) and ammoniated invert cane molasses (33% ACM) is shown in table 2. The nitrogen in 15% ACM and 33% ACM was not available to the microorganisms as urea nitrogen. Furthermore, as ammoniation of the cane molasses was increased to a level of 33% protein equivalent, the carbohydrate portion also became unavailable as indicated by the increase in percent cellulose digested with increasing levels of 33% ACM. One would expect a reduction in cellulose digestion if the carbohydrates were as "readily available" as the carbohydrates in flasks containing urea and sucrose.

Although the nitrogen appeared to be relatively unavailable to the microorganisms taken from an animal fed hay, it might be possible for the microorganisms to adapt to and utilize the nitrogen in the ammoniated cane molasses. To test this hypothesis, a rumen fistulated steer was fed one

pound 33% ACM per day plus timothy hay *ad libitum* for 123 days. The rumen microorganisms were tested for their ability to utilize the nitrogen contained in ammoniated molasses 3 days before and 15, 23 and 123 days after the beginning of the feeding period. Because the carbohydrate in the 33% ACM was shown to be utilized to a limited extent, 0.5 gm. starch was

TABLE 2. AVAILABILITY OF UREA AND AMMONIATED CANE MOLASSES (15% AND 33% PROTEIN EQUIVALENT) NITROGEN FOR BACTERIAL PROTEIN SYNTHESIS AND CELLULOSE DIGESTION

Additions to the basal medium[a]	Mg. nitrogen per 100 ml.			Percent cellulose digested
	Nitrogen added	Ammonia in medium	Prot. syn.	
Ammoniated cane molasses—15% protein equivalent				
None	0	2.5	3.5	8.0
Urea+122 mg. sucrose	7.8	10.3	7.0	40.9
Urea+366 mg. sucrose	23.4	25.9	11.8	47.8
Urea+610 mg. sucrose	39.0	41.5	12.8	23.8
Urea+1220 mg. sucrose	77.9	80.4	11.8	6.8
Urea+2440 mg. sucrose	155.8	158.3	9.8	8.6
367 mg. ammon. cane molasses	7.5	3.8	3.9	20.4
1102 mg. ammon. cane molasses	22.5	6.4	4.2	20.4
1836 mg. ammon. cane molasses	37.5	8.9	6.5	13.6
3670 mg. ammon. cane molasses	75.1	15.3	9.3	9.1
7350 mg. ammon. cane molasses	150.3	28.2	13.1	11.4
Ammoniated invert cane molasses—33% protein equivalent				
None	0	2.5	3.5	8.0
Urea+58 mg. sucrose	7.8	10.3	6.5	33.0
Urea+174 mg. sucrose	23.4	25.9	13.0	39.8
Urea+290 mg. sucrose	39.0	41.5	12.2	40.9
Urea+580 mg. sucrose	77.9	80.4	15.8	31.8
Urea+1160 mg. sucrose	155.8	158.3	12.5	1.2
174 mg. ammon. cane molasses	7.7	3.7	3.0	19.3
521 mg. ammon. cane molasses	23.0	6.1	5.1	21.6
868 mg. ammon. cane molasses	38.3	8.5	7.6	35.2
1740 mg. ammon. cane molasses	76.7	14.5	10.3	47.8
3480 mg. ammon. cane molasses	153.5	26.6	12.4	50.0

[a] 1.0 gm. cellulose, 0.1 gm. glucose, minerals, 10 ml. Sharples suspension of rumen liquor from alfalfa hay fed steer and 10 ml. Sharples supernatant.

added to all *in vitro* fermentation flasks to provide for maximum protein synthesis. The results (table 3) show that feeding the steer ammoniated molasses did not increase the utilization of the "bound" nitrogen in 33% ACM by microflora *in vitro*. Adaptation of the flora to one capable of utilizing this type of nitrogen substrate apparently did not occur or the changes were too subtle to be observed with the technique used.

To determine whether or not the limited nitrogen availability was

TABLE 3. AVAILABILITY OF UREA AND AMMONIATED INVERT CANE MOLASSES (33 PERCENT PROTEIN EQUIVALENT) NITROGEN FOR BACTERIAL PROTEIN SYNTHESIS AND CELLULOSE DIGESTION 3 DAYS BEFORE AND 15, 23 AND 123 DAYS AFTER FEEDING ONE POUND AMMONIATED CANE MOLASSES PER DAY TO A FISTULATED STEER

	Mg. nitrogen per 100 ml.						
			Protein synthesized				
Additions to the basal medium[a]	Nitrogen added	Ammonia in medium	3 days before	15 days after	23 days after	123 days after	Av. percent cellulose digested
None	0	0.9	1.5	−1.0	0.4	1.1	0.5
Urea	4	4.9	3.5	4.5	2.9	4.7	2.1
Urea	8	8.9	6.0	9.5	4.9	7.3	7.7
Urea	16	16.9	11.0	12.0	9.4	....	20.9
Urea	24	24.9	16.0	14.5	11.9	14.8	39.4
Ammon. cane molasses	4	1.5	2.5	2.5	1.4	2.1	0
Ammon. cane molasses	8	2.1	2.0	2.0	1.4	2.5	0
Ammon. cane molasses	16	3.4	4.0	3.5	1.9	...	0
Ammon. cane molasses	24	4.6	4.5	5.5	2.4	4.1	0

[a] 1.0 gm. cellulose, 0.1 gm. glucose, 0.5 gm. starch, minerals, 10 ml. Sharples suspension of rumen liquor from timothy hay, ammoniated molasses-fed steer and 20 ml. Sharples supernatant.

TABLE 4. AVAILABILITY OF THE NITROGEN IN UREA, AMMONIATED FURFURAL RESIDUE, AMMONIATED CORN COBS, D-GLUCOSAMINE, N-(D-GLUCOSYL)-GLYCINE ETHYL ESTER AND N-(D-GLUCOSYL)-DIETHANOLAMINE TO BOVINE RUMEN MICROORGANISMS

	Mg. nitrogen per 100 ml.			
Additions to the basal medium[a]	Nitrogen added	Ammonia in medium	Prot. syn.	Percent cellulose digested
None	0	1.5	1.2	0
Urea	5.0	6.5	5.1	3.2
Urea	10.0	11.5	8.2	8.3
Urea	25.0	26.5	14.0	32.1
Urea	50.0	51.5	20.6	74.0
Ammon. furfural residue	10.0	7.1	4.6	0
Ammon. furfural residue	25.0	15.6	10.3	2.2
Ammon. furfural residue	50.0	29.7	19.2	8.5
Ammon. corn cobs	10.0	2.1	0.4	2.2
Ammon. corn cobs	25.0	3.0	3.0	2.6
Ammon. corn cobs	50.0	4.5	3.4	2.6
D-glucosamine	10.0		8.8	8.8
N-(D-glucosyl)-glycine ethyl ester	10.0		2.6	8.8
N-(D-glucosyl)-diethanolamine	10.0		2.1	6.6

[a] 1.0 gm. cellulose, 0.1 gm. glucose, 0.5 gm. starch, minerals, 10 ml. Sharples suspension of rumen liquor from alfalfa hay fed steer and 10 ml. Sharples supernatant.

specific for ammoniated cane molasses, several other ammoniated carbohydrate residues, prepared in limited research quantities, were tested for nitrogen availability and the results appear in table 4. Using cellulose digestion as the criteria, the ammoniated residues showed very limited nitrogen availability. It should be observed, however, that the nitrogen of the primary amine, D-glucosamine, was available to the rumen microorganisms; whereas, the microorganisms were apparently unable to degrade the secondary and tertiary glucosamines tested (N-(D-glucosyl)-glycine ethyl ester and N-(D-glucosyl)-diethanolamine, respectively).

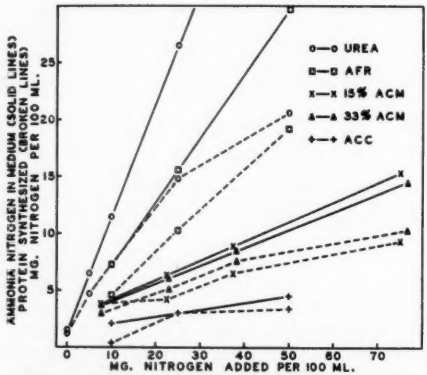

Figure 2. The effect of ammonia nitrogen in the fermentation medium on protein synthesis in vitro by bovine rumen microorganisms. Ammoniated furfural residue (AFR); ammoniated cane molasses (ACM); ammoniated corn cobs (ACC).

A closer examination of the protein formed in each flask (table 4 as well as tables 2 and 3) suggests that protein synthesis and bacterial growth are related to the ammonia nitrogen in the medium. This effect is readily observed in figure 2 in which the amount of protein synthesis (broken lines) does not exceed the amount of ammonia nitrogen (solid lines) in the medium at the beginning of the fermentation.

Recently, ammoniated bagasse and an ammoniated bagasse extract were tested *in vitro* for nitrogen availability. As was observed with the other samples tested, only the "free" ammonia nitrogen in the samples was available to the rumen microorganisms.

These results, therefore, more critically assess the value of these ammoniated carbohydrate residues than previous reports, and are in agreement with the *in vitro* results of Davis *et al.* (1955) and the *in vivo* digestion trials of Tillman *et al.* (1957a,b) who showed that the ammoniated resi-

dues tested thus far are of limited value as protein extenders in ruminant feeds.

The experiments reported emphasize the importance of properly designed *in vitro* fermentation trials as basic and valuable tools for the evaluation of new feed components.

On the basis of the results obtained, it is evident that only the "free" ammonia in the ammoniated residues is available to the microorganisms for growth. The remaining "bound" nitrogen does not appear to be toxic to the microorganisms. An apparent parallel is found in the report by Belasco (1954) in that the nitrogen in many amides, urea derivatives and amidines is not readily available to rumen microorganisms for growth. The substrate specificity of urease is presumably the explanation for the limited utilization of the nitrogen compounds studied by Belasco. While the explanation for the results reported herein are probably complex, the inability of the microflora to hydrolyze or degrade the "bound" nitrogen is an important part of the explanation for the results obtained.

Summary

Ammoniated cane molasses (15% protein equivalent), ammoniated invert cane molasses (33% protein equivalent), ammoniated corn cobs, ammoniated furfural residue, ammoniated bagasse and ammoniated bagasse extract were tested *in vitro* as sources of nitrogen for rumen microorganisms.

It was found that rumen microorganisms utilized only the ammonia in these products and that the microorganisms did not utilize the "bound" nitrogen in ammoniated invert cane molasses even after an "adaptation period" of 123 days.

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DIGESTION STUDIES WITH OAT SILAGES USING A NEW FECAL COLLECTION TECHNIQUE[1, 2]

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RECENT interest in oat silage and the paucity of data in the literature have indicated a need for more information on the relative value of oats cut at different stages of maturity. Available data suggest a rapid decrease in value of oat forage with increased stage of maturity. Meyer *et al.* (1957) reported a decrease in the TDN (total digestible nutrient) content of oat hay from 68.0 in the jointing stage to 50.0 in the milk stage. Also, Stallcup and Horton (1957) showed TDN values of 71.3, 58.4 and 58.8 for fall-sown Arkwin oats harvested for silage in the boot, milk and hard-dough stages, respectively. A TDN value of 63.2 was reported by Lassiter *et al.* (1957) for early-dough stage oat silage. Earlier work on dough stage oats was compiled by Schneider (1947).

This paper reports the effect of stage of maturity on the apparent digestibility and TDN content of oat silage.

Materials and Methods

Clintland oats were harvested for silage in the boot, early-milk and soft-dough stages. The silages were made by the direct-cut method, treated with 6 to 8 lb. of sodium metabisulfite per ton and stored in upright, steel silos. The composition of the silages is presented in table 1.

TABLE 1. PROXIMATE COMPOSITION[a] OF OAT SILAGES

Silage	Protein	Crude fiber	Ether extract	Ash	N-free extract
	%	%	%	%	%
Oats, boot	11.6	32.1	5.0	8.8	42.5
Oats, early-milk	10.5	30.7	4.0	8.7	46.1
Oats, soft-dough	9.6	30.0	3.7	9.8	46.9

[a] Dry matter basis.

The coefficients of digestibility were obtained with nine 8-month-old Holstein bulls which previously had been on a high roughage program. For 3 months prior to the digestion trial, these animals were on a grass-legume silage experiment and prior to that they were on a pasture experiment. Three animals were assigned at random to each of the three silages. A 21-day preliminary period was followed by a 7-day fecal collection period.

[1] Contribution from the Dairy Department, Journal Paper No. 1323.
[2] Plastic bags used in this experiment were furnished by the Visking Company, Terre Haute, Indiana.
[3] Lafayette, Indiana.

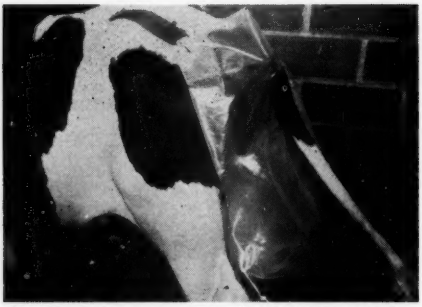

Figure 1. Animal with bag attached ready for fecal collection.

The animals were clipped and three pieces of webbing were fastened to each animal with branding cement. Two pieces were fastened to the animals as shown in figure 1 and the other was fastened underneath as reported by Noller *et al.* (1956). The straps were securely cemented before the bags were attached. Shower curtain rings were attached to the top of the bags and in turn the top straps were passed through them and fastened with safety pins (figure 1). The underneath flap was passed around the strap and fastened with a safety pin. Adjustments were made for the bag to fit properly.

The animals were kept continuously in stanchions and the feces collected in 6-mil polyethylene bags as shown in figure 1. The bags, which were

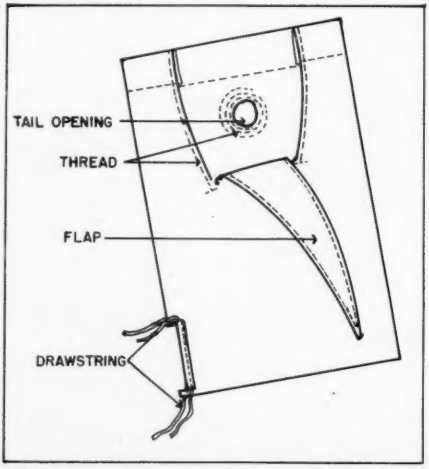

Figure 2. Prepared plastic bag ready for use.

15 in. wide and 24 in. long, were made as shown in figure 2. The tail opening was cut to fit snugly so that as the animal raised its tail to defecate the bag opened to catch the feces.

The length of time the bags could be used was increased by reinforcing them with No. 50 thread (figure 2). The bags were sewed by machine. A drawstring was used to facilitate rapid and easy removal of the feces without removing the bags. Some bags, which were not removed at any time during the 7-day fecal collection, were still usable at the end of the collection period.

The fresh feces were weighed daily and a 2% aliquot removed and stored in a refrigerator. After completion of the 7-day fecal collection period, the samples were mixed, dried, ground and proximate analyses made according to A.O.A.C. methods (1950). Digestion coefficients were calculated and the standard error of the means determined as suggested by Snedecor (1946).

Results and Discussion

The fecal collection technique used in this investigation was inexpensive and easy to use, although it would not appear to be satisfactory for animals unless confined. No difficulty was encountered in making total fecal collections.

Since the entire weight of the bag and its content are supported by the two back straps, satisfactory use depends on the amount of feces voided and the number of fecal collections made daily. In this investigation fecal collections were made four times daily. Although this technique would lend itself to various situations, it would be particularly appropriate where certain collection facilities are not available or are costly.

The digestion coefficients and standard errors of the means for the various silage fractions are presented in table 2. The data indicate a rapid decline in the apparent digestibility of the various fractions except ether extract as the oat plants matured. Similarly, there was a rapid decrease in the TDN value of the silage as the plants matured, owing in large measure

TABLE 2. APPARENT DIGESTION COEFFICIENTS, TOTAL DIGESTIBLE NUTRIENTS AND THEIR STANDARD ERRORS OF THE MEAN

Items	Oat silages					
	Boot		Early-milk		Soft-dough	
	%		%		%	
Dry matter	67.2	.71	61.4	.78	54.9	.93
Organic matter	69.6	.86	63.7	.78	57.1	1.28
Protein	60.1	1.26	58.0	.66	46.1	1.39
Crude fiber	76.6	1.13	68.9	1.00	62.4	1.42
Ether extract	56.7	1.68	55.4	3.48	54.7	7.95
Nitrogen-free extract	68.4	1.26	62.2	1.03	56.3	.89
TDN	67.0	.69	60.9	.57	54.1	1.29

to a decrease in value of the crude fiber and nitrogen-free extract fractions. There was a daily decrease of 1.3% TDN between the boot and early-milk stages and 1.6% TDN between the early-milk and soft-dough stages. The data indicated small variations within animals fed the same silage.

As the stages of maturity advanced from the boot to the soft-dough stage, the protein, crude fiber and ether extract decreased (table 1). The protein content of the silages was lower than that reported by other workers for different varieties cut at comparable stages of maturity (Stallcup and Horton, 1957; Meyer *et al.*, 1957). The crude fiber at the boot stage was higher and also more digestible than that at the early-milk and soft-dough stages.

The decreased TDN content at the soft-dough stage as compared to the early-milk stage is not in agreement with Stallcup and Horton (1957), who reported no difference in TDN content of milk and hard-dough stages of oat silages. However, Meyer *et al.* (1957) reported an increase in TDN content with grain formation. These differences may be due to oat variety or interpretation of stage of maturity, considering the rapid changes occurring during the grain formation stage. In the present experiment, there were 7 days between each of the harvest dates.

Summary

Nine 8-month-old Holstein bulls were used to determine the apparent digestibility of oat silage made of oat forage harvested in the boot, early-milk and soft-dough stages. Total fecal collections were made in 6-mil polyethylene bags described herein. The TDN content of the silages for boot, early-milk and soft-dough stages was 67.0, 60.9 and 54.1%, respectively. During the 14-day interval between the boot and soft-dough stages, TDN decreased 1.4% daily.

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GONADOTROPHIC AND LACTOGENIC HORMONE POTENCIES OF GILT PITUITARIES DURING THE ESTROUS CYCLE AND PREGNANCY [1]

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ENDOCRINE interrelationships existing between the pituitary gland and the ovaries play an important part in mammalian reproductive efficiency. In order to have a better understanding of reproduction in swine it is desirable to determine the gonadotrophic and lactogenic hormone potencies of the pars anterior of the pituitary of the female at different stages of reproduction. According to Nalbandov (1958) the luteotrophic substance is lactogenic hormone in the rat and possibly in the ewe. However, this relationship has not been established in the gilt.

The investigation presented here deals with a comparative evaluation of the follicle stimulating hormone (FSH), the lutenizing hormone (LH) and the lactogenic hormone potencies of the pars anterior from individual gilts at different stages of the estrous cycle and pregnancy. The bioassay of pars anterior tissue is complicated by the presence of the gonadotrophic complex. Assay responses designed to evaluate one component of the complex may be influenced synergistically as well as antagonistically by other substances, including hormones, present in the material being assayed. Evans and Simpson (1950), Nalbandov (1953) and Cowie and Folley (1955) have indicated some of the difficulties encountered in obtaining potency evaluation by bioassay methods for FSH, LH and lactogenic hormone in pituitary preparations.

Experimental Procedure

Thirty gilts of the Duroc and Landrace breeds were divided into five groups each consisting of three Duroc and three Landrace gilts. The group designations were based on three stages of the estrous cycle and two phases of the gestation period. Gilts in Group A were slaughtered on the second day of the estrous cycle (estrus), Group B between the 10th and 12th day (diestrum), Group C on the 18th or 19th day (proestrum), Group D on the 25th day of pregnancy and Group E on the 85th day. All gilts used in this investigation had been farrowed within an

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interval of 33 days. The pituitaries were removed at the time of slaughter, frozen immediately and stored until assayed. At the time of the assay the pars anterior was dissected free from other parts of the gland, acetone dried in a refrigerator, ground, and suspended in 0.85% saline for injection. Individual weights were taken of the pars anterior of each pituitary before and after drying. Potency values for FSH, LH and lactogenic hormones were determined on each gland. The experiment was designed to assay each pituitary at the following dose levels: 4.7 and 9.3 mg. in the FSH assay, 3.5 and 10.5 mg. in the LH assay, and 0.2 and 0.4 mg. in the lactogenic hormone assay. However, some individual glands did not furnish sufficient material to include the 10.5-mg. level in the LH assay. In these cases two rats were injected at the 3.5-mg. level instead of one rat per dose level. Each gland was assayed by one rat per dose level in the FSH assay. In the lactogenic hormone assay, one pigeon was injected per dose level for each pituitary with a replication being obtained by injecting both the right and left side of the crop sac. Each injection site was considered an independent assay since the response is local.

An estimate of the FSH potency was obtained by injecting 22-day-old hypophysectomized female rats. The assay animals were injected twice daily for 3.5 days and autopsied one day following the last injection. The ovarian and uterine weights were used to measure the FSH potency of the injected material. Control assay animals were injected with 0.85% saline. The bioassay for LH potency was performed on 21-day-old male rats. The assay animals were injected twice daily for 4.5 days and autopsied on the day after the last injection. Weights of the ventral prostate, seminal vesicles and levator ani were obtained. Control rats were injected with 0.85% saline. The FSH and LH assay procedures used are described by Hamburger (1950).

The assay for lactogenic hormone potency of the pars anterior was conducted on young pigeons by the intradermal injection procedure of Meites and Turner (1950). The dried pituitary powder, suspended in 0.85% saline, was administered once daily for 4 days by intradermal injection over the crop gland. Control birds were injected with 0.85% saline. On the day following the last injection, the pigeons were killed and each crop sac was dissected out and examined by transmitted light for evidence of crop-gland proliferation. The response was evaluated as O, +, ++ and +++ and coded as 0, 1, 2 and 3.

Results

The reproductive data obtained on the gilts are presented in table 1. The results of the bioassays for FSH, LH and lactogenic hormone potencies for three stages of the estrous cycle and two of pregnancy are summarized in tables 2, 3 and 4, respectively. The data obtained from the FSH and lactogenic hormone assays were analyzed statistically as a

TABLE 1. REPRODUCTIVE DATA FOR GILTS USED IN PARS ANTERIOR ASSAYS

Stage of gilt	Number of gilts	Slaughter weight	Follicles over 8 mm.	Corpora lutea	Embryonic mortality	Wet-weight of pars anterior	Dry-weight of pars anterior
days		lb.	no.	no.	%	mg.	mg.
Estrous cycle							
2	6	217	2[a]	9	..	179	38
10–12	6	220	0	14	..	174	39
18–19	6	249	11	0	..	174	38
Pregnancy							
25	6	286	0	14	35	190	41
85	6	299	0	14	47	222	50

[a] One gilt included in averages had 12 mature follicles on ovaries but had not ovulated.

TABLE 2. FSH ASSAY DATA

Stage of gilt	Number of rats	Average body weight	Ovarian weight[a]	Uterine weight[a]
days		gm.	mg.	mg.
Estrous cycle				
2	12	70	21	85
10–12	12	70	29	125
18–19	12	71	36	131
Pregnancy				
25	12	71	46	116
85	12	70	48	131
Control rats	8	68	23	38

[a] Ovarian and uterine weights represent the mean averaged over two levels and two breeds.

TABLE 3. LH ASSAY DATA

Stage of gilt	Av. body wt.[a]	Ventral prostate		Seminal vesicles		Levator ani	
		3.5[b]	10.5[b]	3.5	10.5	3.5	10.5
days	gm.	mg.	mg.	mg.	mg.	mg.	mg.
Estrous cycle							
2	71	51(9)[c]	37(3)	15	13	22	19
10–12	71	51(7)	70(4)	18	21	25	25
18–19	71	51(9)	61(3)	15	18	22	20
Pregnancy							
25	71	58(8)	70(3)	18	20	25	25
85	69	57(6)	77(6)	18	26	25	28
Control rats		44(5)		13		25	

[a] Averages computed for rats treated on the 3.5-mg. level. Average body weights in gm. for rats receiving the 10.5-mg. dose were 70, 71, 65, 72, and 73, respectively, from estrus to 85 days of pregnancy.

[b] Dose levels of dry pars anterior in mg.

[c] Number of rats included in average. The same number is applicable for seminal vesicles and levator ani measurements.

TABLE 4. LACTOGENIC HORMONE ASSAY DATA

Stage of gilt	Number of pigeons	Average body weight	Number of determinations	Average response[a]
days		gm.		
Estrous cycle				
2	12	450	24	0.92
10–12	12	464	24	1.04
18–19	12	486	24	1.23
Pregnancy				
25	12	480	24	1.46
85	12	462	24	1.87

[a] Average response based on two levels injected: 0.1 mg. and 0.2 mg. dry pars anterior. Crop response coded as 0, 1, 2 and 3, respectively.

5x2x2 factorial arrangement. The analysis for LH content represented a 5x2 factorial design as levels were not included in the analysis because of the number of missing values on the higher level. The analysis of variance of assay data is presented in table 5.

Discussion

Reproductive data on 30 gilts used to furnish material for hormone assay are presented in table 1. The embryonic mortality rate in gilts slaughtered on the 25th day of pregnancy varied between 13 and 53%, the average being 35%. The maximum embryonic loss calculated in gilts pregnant 85 days was 64% and the minimum observed was 17% with a 47% average. The average wet and dry weights for the pars anterior indicate that an increase in the weight of this organ occurs with an increase in body weight. The correlation coefficient between body weight

TABLE 5. ANALYSIS OF VARIANCE OF HORMONE ASSAY DATA

Source of variation	FSH assay			Lactogenic hormone assay		LH assay			
	d.f.	Uterine wt. M.S.	Ovarian wt. M.S.	d.f.	M.S.	d.f.	Ventral prostate wt. M.S.	Seminal vesicles wt. M.S.	Levator ani wt. M.S.
Treatments	(19)	(1922)**	(829)**	(19)	(2.1)[a]	(9)	(85)	(23)	(32)*
Stage of cycle	4	4414**	1497**	4	2.8[a]	4	76	18	19
Breed	1	6596**	2901**	1	0.2	1	2	64*	93**
Level	1	4744**	2807**	1	20.0**	..	..	..	..
S x B	4	668	697*	4	0.1	4	115	18	30*
S x L	4	502	262	4	1.9	..	..	..	..
B x L	1	33	140	1	0.1	..	..	..	..
S x B x L	4	700	21	4	0.3	..	..	..	..
Error	40	463	194	40	1.2	20	78	13	10
Sampling error	..	...	...	60	0.3	..	..	..	..

** P less than 0.01.
* P less that 0.05.
[a] P less than 0.10.

and dry weight of the pars anterior was 0.43 which was significant at the 2% level. It was shown by covariance analysis that the differences among the mean dry pars anterior weights for the stages studied was not significant when adjusted for differences in body weights of the gilts. Consequently, the heavier gland weights recorded for pregnant gilts appear to be the result of differences in body weight and not a result of differences in the reproductive stage of the gilts when slaughtered. Hollandbeck *et al.* (1956) reported that the dry weight of swine pituitary glands increases linearly with age.

The average age of the Duroc and Landrace gilts when slaughtered was 246 and 249 days, respectively. Duroc gilts weighed an average of 15 lb. more than Landrace gilts when slaughtered. The breed difference in the average dry weight of the pars anterior of the pituitary was 6.7 mg., the Duroc glands averaging 44.4 mg. and the Landrace 37.7 mg.

Significant differences ($P<0.01$) in FSH potency were found among reproductive stage means in both the ovarian and uterine weight assays. An increase in the dose level from 4.7 mg. to 9.3 mg. resulted in an increase in the average uterine weights ($P<0.01$), (table 5).

The FSH potency (table 2) obtained for the second day of the estrous cycle was lower than all other stages studied ($P<0.05$). These data are in agreement with the low gonadotrophic potency values observed at this stage of the cycle by Faiermark and Lingerman (1938). Robinson and Nalbandov (1951), using the chick assay, observed a marked increase in gonadotrophic potency of swine pituitaries on the eighth day of the estrous cycle. A direct comparison of the rat assay data presented here cannot be made with the results of Robinson and Nalbandov (1951) but it is noted that the FSH concentration level had increased significantly ($P<0.05$) by the 10th to 12th day of the cycle. This increase was observed in both the ovarian and uterine weight data. It was found that the FSH concentration in the pars anterior of the pituitary at early proestrum is approximately equal to the FSH potency 10 to 12 days after estrus. Robinson and Nalbandov (1951) reported similar findings in an assay of the total gonadotrophic activity of pituitaries collected from cycling gilts.

The data obtained from the uterine weight assay employed indicate the FSH potency in the pars anterior is lower on the 25th day of pregnancy than during early proestrum or the 85th day of gestation ($P<0.05$). This decrease in gonadotrophic potency during early pregnancy was observed by Faiermark and Lingerman (1938), and they have suggested the decrease is the result of estrogen inhibition since a marked increase in estrogen concentration occurs between the 20th and 30th day of pregnancy. Bredeck and Mayer (1958) have reported that estrogen execretion occurs in the urine of pregnant sows at the time of placentation.

Since the estrogen concentration in the urine has been demonstrated to be at a relatively high level on the 25th day of pregnancy, the low FSH

potency observed in swine pituitaries representing early pregnancy is in agreement with the accepted theory of estrogen inhibition on the secretion of FSH by the pituitary (Turner, 1955). However, Bredeck and Mayer (1958) reported the amount of estrogens found in swine urine during the third week of pregnancy is less than that observed for the 12th week of gestation. Therefore, the increased FSH activity recorded for the later stages of pregnancy does not show an inverse relationship to the estrogen concentration as suggested by the estrogen inhibition theory. Robinson (1950) and Hollandbeck *et al.* (1956) found that the total gonadotrophic activity of the pituitary decreases in a steady manner with the advancement of pregnancy. Hollandbeck *et al.* (1956) stated the decline in potency may be explained by the inhibiting effect of estrogen on the formation of gonadotrophic hormone.

No significant differences were found among the LH potency means at the different reproductive stages (table 3). However, the mean values obtained furnish evidence that the LH secretion rate is actually higher during pregnancy than estrus or early proestrum. Of the eight average values calculated for the ventral prostate and seminal vesicle responses during pregnancy, all were higher than the comparable mean weights recorded for estrus and early proestrum (table 3). A similar comparison of the mean weights recorded for the diestrum phase of the estrous cycle also suggests the LH potency to be highest when fully developed corpora lutea are present on the ovaries. The levels of pars anterior material administered in the assays did not elicit a response in the levator ani.

The lactogenic hormone potency of the pars anterior showed a linear increase with advancing stages of the estrous cycle and pregnancy (table 4). The data suggest the secretion rate of this pituitary hormone is higher in pregnant gilts than cycling gilts. The differences among reproductive stage means were found to be statistically signficant at the 10% level (table 5).

Significant differences ($P<0.01$) between Duroc and Landrace means were found in the analysis of the ovarian and uterine weight data in the FSH assay and for the levator ani response in the LH assay (table 5). This breed difference was not detected in the ventral prostate response or the lactogenic hormone assay. Hollandbeck *et al.* (1956) found pituitaries from pregnant Hampshire sows to have a significantly higher gonadotrophic potency than those collected from pregnant Duroc sows.

The higher FSH and LH potency values observed for Landrace gilts were not accompanied by a breed difference in the number of ova shed at the estrus prior to the time of slaughter. However, the number of corpora lutea recorded for 18 gilts representing diestrum and pregnancy was determined as long as 85 days previous to the determination of the FSH and LH potency values. In turn, the relationship existing between the concentration of the hormones studied and the corpora lutea number

is considered to be of limited value in making a comparison of the potency estimates and ovulation rates for the two breeds.

A further evaluation of the breed difference in the FSH and LH potency of the pars anterior was made by computing the total potency of the glands. It was found in this comparison that the ovarian, uterine and seminal vesicle responses indicate a higher total potency of FSH and LH in the pars anterior of the Landrace gilts, as well as a higher concentration per unit gland weight. However, the difference between the two breeds was reduced in magnitude due to the heavier glands obtained from the Duroc gilts.

Summary

Pituitaries were obtained from gilts slaughtered during estrus, diestrum, early proestrum and at the 25th and 85th days of pregnancy. The FSH potency of the pars anterior 2 days after the onset of estrus was significantly lower than at all other stages studied ($P<0.05$). There was little difference between the FSH potency at 10 to 12 days after the onset of estrus and that found during early proestrum. The difference between the FSH potency means for early and late pregnancy, as determined by the uterine weight assay, was statistically significant ($P<0.05$). The higher FSH potency at 85 days of pregnancy does not appear to be in agreement with the estrogen inhibition of FSH production by the pars anterior.

Although differences among reproductive stage means in the LH assay were not statistically significant, the average weights of the ventral prostate and seminal vesicles of the assay animals indicate the LH potency is higher in pregnant gilts than in gilts slaughtered during estrus or early proestrum. Significant differences, at the 10% level, in lactogenic hormone potency were found among the reproductive stage means. The lactogenic hormone potency was higher in pregnant gilts than in non-pregnant gilts. An increase in lactogenic hormone potency was found with increases in time after estrus.

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THE EFFECT OF FORAGE ASH AND LOW CHROMOGENS LEVEL OF FECES UPON THE DETERMINATION OF DIGESTIBILITY BY THE FECAL CHROMOGENS METHOD [1]

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THE determination of digestible dry matter of forages by the use of the "chromogens" technique proposed by Reid *et al.* (1950, 1952) has been widely accepted and has usually produced satisfactory results (Hardison and Reid, 1953; Hardison *et al.*, 1954; Kane *et al.*, 1950, 1953; McCullough, 1953; Reid *et al.*, 1952). With some types of forage, however, this method has been reported to be unsatisfactory. Cook and Harris (1951) reported the chromogen technique to be in considerable disagreement with the lignin ratio method, the latter yielding reasonable calculated intake values while the chromogen ratio technique did not. However, when the fecal chromogens method of Reid *et al.* (1952) is applied to the data of Cook and Harris there is good agreement between the lignin ratio method and fecal chromogens method in three of five forage species reported. Sampling difficulties due to selective grazing may account for some of the discrepancy noted in the other forage species (Hardison *et al.*, 1954). One would expect that representative "plucked" samples would be more difficult to obtain from some of the desert range plants than from the more usual pasture plants. Squibb *et al.* (1958) compared the chromogen ratio method to standard digestion trials with kikuyu grass and ramie. For the kikuyu grass the two methods agreed very well but they differed widely for the ramie.

Reid *et al.* (1952) reported that complete extraction of "chromogens" from forages (particularly mature forages) is often very difficult. They also found that in the forages studied there was a predictable relationship between the fecal chromogens, which are relatively easy to extract, and the forage chromogens. The equation, $Y=(0.0925X+137.3383 \log X)-242.1181$ expresses this relationship. (Y=Units of chromogens/g. dry matter in forage, $\times$= units of chromogens/g. dry matter in feces). There was also a predictable relationship between the fecal chromogens and the digestible dry matter of the forage shown by the equation, $Y=32.74+0.0168X+8.47 \log X$ (Y=percent digestible dry matter, X=units of chromogens/g. dry matter in feces). With either of the above equations extraction of chromogens from the forages in question is not required. This fact makes them especially applicable to studies in which the chromogens are difficult to extract from the forage or in which truly representative forage samples are not available. The latter situation is

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found in most grazing experiments because it is difficult, if not impossible, to obtain samples of forage which represent the forage consumed by the grazing animals (Hardison *et al.*, 1954).

The following is a report of the use of the above equations with data obtained from digestion studies with lima bean vine silage which shows the effect of using them (1) with materials which yield a low level of fecal chromogens and (2) with forages which have a high ash content.

Experimental

The digestibility by dairy animals of the silage made from lima bean vines was determined in each of four years. The vines were obtained from nearby commercial viners and were the residue remaining after the beans had been removed. The storage facilities varied from year to year: First year in the bottom of a tower silo, 16 ft. in diameter, without preservative, second and third years in a concrete stave silo, 10 ft. in diameter, with sodium metabisulfite [3] as a preservative, and in the fourth year in a Krene Plastic Portable Silo [4] without preservative. Generally good preservation was obtained except in the first year when the volume of ensilage stored was too small for good preservation and, in addition, too little was removed at each feeding to prevent spoilage.

Conventional trials were conducted during the first two years with Holstein bull calves weighing approximately 400 lb. Lima bean vine silage was the sole ration. After the animals were standardized as to level of intake, they were maintained on that intake for a ten-day preliminary period which was then followed by a ten-day collection period. In the last two years dairy heifers weighing 600–750 lb. were used in indicator trials in which 7.5 gm. Cr_2O_3 were administered twice daily at 6:00 a.m. and 4:00 p.m. in gelatin capsules. Grab samples of feces were taken at the same times in a four-day collection period which had been preceded by a period of about 16 weeks in which the lima bean silage had been the main portion of the ration and immediately by a ten-day period in which the silage only was fed at a constant level.

In all four years digestibility was determined also by Reid's fecal chromogens method and by the chromogens ratio method in which the forage chromogen level was calculated from the fecal chromogens (Reid *et al.*, 1952).

Dry matter was determined indirectly by toluene distillation (Bidwell and Sterling, 1925). The ash content was determined by the conventional ashing method (A.O.A.C., 1955). Chromium oxide was determined in the first two trials by the method described by Kane *et al.* (1950), and in the last two trials by the method of Christian and Coup (1954).

[3] Provided by Allied Chemical and Dye Corporation.
[4] Provided by Bakelite Company, a Division of Union Carbide and Carbon Corporation.

Results and Discussion

The chromogens and ash contents of the feces and the apparent digestibility of the dry matter determined by the conventional or chromium oxide method compared to the fecal chromogens method are shown in table 1. When the ash content of the forage consumed was at a moderate level there was good agreement between the chromogens method and conventional, or Cr_2O_3, method. As the ash content increased there was a progressively greater disparity between the methods. The variation in ash content was due to weather conditions at the time of harvest. In harvesting, the lima bean vines are pulled; therefore, the residue includes the roots and the soil clinging to them.

It is reasonable to assume that all of the chromogen materials in both

TABLE 1. THE CHROMOGEN CONTENT OF FECES, THE ASH CONTENT OF FORAGE AND FECES, AND THE DIGESTIBLE DRY MATTER OF LIMA BEAN VINE SILAGE

Animal number	Fecal chromogens[a]	Ash in—		Digestible dry matter—	
		Feces	Forage	Conventional or Cr_2O_3	Fecal chromogens[b]
	Unit/g.	%	%	%	%
Trial I					
1	182.9	18.1	10.6	53.0	55.0
2	184.1	18.5		53.6	55.0
Mean	183.5	18.3		53.3[c]	55.0
Trial II					
1	179.5	34.6	19.2	48.7	54.8
2	181.1	32.8		47.4	54.9
3	188.7	32.7		49.4	55.2
Mean	183.1	33.4		48.5[c]	55.0
Trial III					
1	83.7	50.3	30.9	38.5	50.4
2	99.3	55.2		38.9	51.3
3	89.1	47.9		31.0	50.8
Mean	90.7	51.1		36.1[d]	50.8
Trial IV					
1	131.1	43.3	26.8	39.2	52.9
2	115.2	42.4		33.3	52.1
3	144.6	49.5		44.6	53.5
4	145.7	47.0		47.4	53.5
Mean	134.2	45.6		41.1[d]	53.0

[a] Standardized with Reid's units. Exchange of samples with Reid made this possible.
[b] Calculated by Reid *et al.* (1952) equation $Y=32.74+0.0168\ X+8.47$ log X. Y=% digestible dry matter; X=Units of chromogens/g. dry matter in feces.
[c] Conventional trial.
[d] Cr_2O_3 trial.

TABLE 2. A COMPARISON OF DIGESTIBLE ORGANIC MATTER DETERMINED FROM CHROMOGENS PER UNIT OF FECAL ORGANIC MATTER AND EITHER CONVENTIONAL OR CHROMIC OXIDE DETERMINATIONS

Animal number	Fecal chromogens units per gram organic matter	Digestible organic matter by—	
		Fecal chromogens method [a]	Conventional or Cr_2O_3 method
		%	%
Trial I			
1	222.0	56.4	57.0
2	226.2	56.5	57.7
Mean	224.1	56.4	57.4 [b]
Trial II			
1	274.5	58.0	58.5
2	269.9	57.9	56.2
3	279.9	58.2	57.9
Mean	274.8	58.0	57.5 [b]
Trial III			
1	168.4	54.4	55.7
2	221.7	56.3	60.4
3	171.0	54.5	47.9
Mean	187.0	55.1	54.7 [c]
Trial IV			
1	227.6	56.5	52.9
2	206.1	55.8	47.5
3	267.3	57.8	61.8
4	279.1	58.2	61.9
Mean	245.0	57.1	56.0 [c]

[a] Calculated by Reid *et al.* (1952) equation $Y=32.74+0.0168X+8.47 \log X$, converted to an organic matter base. Y=percent digestible organic matter; X=Unit of chromogens/g. organic matter in feces.

[b] Conventional trial.

[c] Cr_2O_3 trial.

the forage and feces are associated with the organic matter present. This seems so because they are apparently chlorophyll and its degradation products (Davidson, 1954; Irvin and Wiseman 1953; and Smart *et al.*, 1953). The marked differences in results between the methods mentioned above appear to be associated with the level of ash diluting the organic matter and therefore the chromogen content of both the forage and the feces. Because of this, it was considered desirable to express the digestibility in terms of digestible organic matter. The comparative digestibilities when this is done are shown in table 2. The agreement between the methods is now good.

In certain of the trials in which the chromogen content of the feces was low it was noted that unrealistic digestibility values were obtained when calculated by the method of forage chromogens concentration: feces chromogens concentration ratio if the forage chromogens concentra-

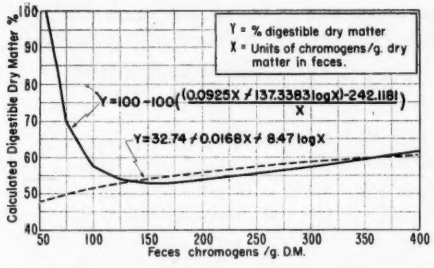

Figure 1. Comparison between digestible dry matter determined by (A) direct calculation from fecal chromogen levels, - - - - and (B) calculated indirectly from estimated forage chromogen levels —— (Reid et al., 1952).

tion had been calculated by the equation of Reid *et al.* (1952) shown in the introduction above. As a result of this observation the digestibilities of hypothetical samples in which low fecal chromogens are obtained were calculated by both the fecal chromogens method and by the ratio method. The results are shown in figure 1. It can be readily seen that the ratio technique (solid line) is not accurate in the low fecal chromogen range (below 125) if the Reid *et al.* (1952) equation for calculating the forage chromogens is used. Their equation is based upon observations over a range of higher values and a new equation is needed if this method is to be used in the range of lower values. A reasonable determination of dry matter digestibility can apparently be obtained by using the equation calculating the digestible dry matter directly from the fecal chromogens. If an estimate of the forage chromogen content is needed it can be calculated by a modification of the fecal chromogens equation for determining digestible dry matter as follows:

Digestible dry matter$=32.74+0.0168X+8.47 \log X$ (Equation A).

Digestible dry matter by ratio method $=$

$$100-\left[100\ \frac{\text{(Units of forage chromogens per g. dry matter)}}{\text{(Units of fecal chromogens per g. dry matter)}}\right] \quad \text{(Equation B)}.$$

It follows then that equation A=equation B because both are equal to the digestible dry matter and the forage units[5] per gram of dry matter is represented by the following equation where Y=forage chromogens and X=fecal chromogens (both in units per gram of dry matter).

$Y=X(.6726-.0002X-.0847 \log X)$.

[5] The "units" used are Reid's units which are arbitrary. Exchange of samples with Reid has enabled use of the same unit.

As an alternative the forage concentration of chromogens can be obtained after the digestibility is calculated by the equation:

$$Y = X \frac{(1 - \text{digestible dry matter})}{100}.$$

When the forage fed contains considerable ash the fecal chromogens method must be placed on an organic matter base to yield valid digestibility data. When low levels of fecal chromogens are encountered, digestibility calculations are not reliable when based upon calculated forage chromogens obtained from fecal chromogens levels using the Reid *et al.* (1952) equation which was calculated from higher fecal chromogens levels.

Summary

In four digestion trials with lima bean vine silage it was noted that as the ash content of the forage increased there was an increasingly large difference between apparent digestibility obtained by the fecal chromogens method and that from either the conventional method or the chromic oxide method. With 10.6% ash, the digestible dry matter was 53.3% and 55.0%; with 19.2% ash, it was 48.5% and 55.0% for the conventional and fecal chromogens methods, respectively; when the ash content of the forage was 26.8%, the digestible dry matter was 41.1% and 53.0%, and with 30.9% ash it was 36.1% and 50.8% for the chromic oxide and fecal chromogens methods, respectively. When the digestibility was expressed on an organic matter basis the results were as follows: 57.4% and 56.4%, 57.5% and 58.0%, 56.0% and 57.1%, and 54.7% and 55.1% for the four trials arranged in the same order as above. When the fecal chromogens level was low (below 125 units per gram of fecal dry matter) it was found that the fecal chromogens method of determining digestibility was still accurate but that the calculated forage chromogens level using Reid's formula was not reliable.

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THE QUANTITATIVE RELATIONSHIP BETWEEN TOTAL DIGESTIBLE NUTRIENTS AND DIGESTIBLE ENERGY VALUES OF FORAGES [1]

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THERE is a close relationship between the two methods of feed evaluation: the digestible energy (DE) method, and the total digestible nutrients (TDN) method. Since both TDN and DE are based on a feed-feces difference, they essentially evaluate feedstuffs to the same degree of availability to the animal body. Swift (1957a), Macdonald (1957), Markley *et al.* (1959), and Barth *et al.* (1959) all reported high correlation between the two methods. Since, however, the TDN method is, time-consuming, empirical, and indirect in approach, use of the DE method is becoming common. For example, the National Research Council includes the DE method in its requirements for dairy cattle, and the Northeast Regional project (NE-24) adopted it for the comparison of the nutritive value of forages. In any change from the TDN to the DE system, however, some method must be found to convert the voluminous TDN data already in existence to DE values. It is the purpose of this paper to present such a conversion factor.

Several factors for the conversion of TDN to DE values have been suggested, some of which have been derived from theory and others from experimental data. A conversion factor which is derived by comparing TDN and DE values determined from one and the same individual digestion trial would seem to be more meaningful than a calculated theoretical factor.

Swift (1957b), using all the simultaneously determined TDN and DE values available in this country and abroad of mixed and roughage rations for cattle and roughage rations for sheep, arrived at the average conversion factor of 2000 Calories per pound of TDN, or 4.41 Calories per gram of TDN. He also stated that the small differences in average TDN-DE conversion factors which existed between cattle and sheep, and also between roughages and mixed rations, were not statistically significant. Crampton *et al.* (1957) studied the caloric value of TDN (calories per gram of TDN) in swine rations. From 30 theoretical rations in which both TDN and DE were calculated, these workers derived a prediction equation by which the TDN-DE conversion factor from the gross energy and crude fat content

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of a specific feed could be estimated. These calculated conversion factors of a variety of rations and their corresponding factors, which were experimentally determined from TDN and DE values of digestion trials with swine, were in good agreement. It was concluded that in swine rations the caloric value of TDN is not a constant but is dependent upon the ether extract content of the ration.

When the results of digestion trials of this station were studied, however, in which roughages alone had been fed to cattle and sheep, ether extract did not seem to have an effect on the magnitude of the TDN-DE conversion factors. This may well be explained by the fact that roughages contain only small amounts of ether extract of which the apparent digestibility is very low. It was also noted that as the caloric value of TDN increased the apparently *digestible protein* content of the roughages was increased.

TABLE 1. THE RELATION OF DIGESTIBLE PROTEIN AND THE CONVERSION FACTORS IN THE ESTIMATION OF DE

Digestible protein	Conversion factor	Digestible protein	Conversion factor	Digestible protein	Conversion factor
%	Cal./gm. TDN	%	Cal./gm. TDN	%	Cal./gm. TDN
1	4.363	8	4.502	15	4.642
2	4.383	9	4.522	16	4.662
3	4.403	10	4.542	17	4.682
4	4.423	11	4.562	18	4.702
5	4.443	12	4.582	19	4.722
6	4.463	13	4.602	20	4.742
7	4.483	14	4.622	21	4.762

In the case of the digestion trial with bromegrass (Barth *et al.*, 1959), the differences were statistically significant ($P<0.01$) as determined by the multiple range test (Duncan 1955).

Maynard (1953) reviewed the changes that have occurred in the TDN system over the years and pointed out why, theoretically, the caloric value of TDN should increase with increasing digestible protein content in a ration. He stated, ". . . TDN does not mean exactly what the term implies, because the long-used method of calculating this takes account of certain urinary losses as well as of undigested nutrients. A lack of appreciation of this fact continues to be responsible for certain errors in the use of TDN in experimental work and in calculating digestible energy." Maynard further explains that this under-valuation of the digestible nutrients is not constant but occurs at an accelerated rate as the protein content of a ration increases. That the conversion factor of TDN to DE (digested calories per gram of TDN) should theoretically increase as the protein content is increased, is evident from table 1 of Crampton *et al.* (1957), where the conversion factors have been calculated from theoretically assumed chemical compositions and apparent digestibilities of various swine rations.

The Problem. If the digestible protein content of a roughage affects the caloric value of TDN in theory and if it was found to be an influence in the digestion trials conducted at this station, the same influence should be exhibited when all the available data on forages are considered. If a close positive correlation is evident between caloric value of TDN and digestible protein, it should then be determined whether or not this correlation is of sufficient practical significance to justify the inclusion of digestible protein in the prediction of DE.

Statistical Proof. All the appropriate TDN and DE data from forages in which both determinations were calculated from one and the same conventional digestion trial with cattle or sheep were assembled and separated into hay values and silage values, and the ratio of TDN and DE (calories per gram of TDN) was calculated for each individual pair of observations. Because no essential difference in the TDN-DE ratio of a specific protein content was observed between hays and silages, they were considered as one group. The correlation coefficient of caloric value of TDN and digestible protein in the roughages was +.64. The following simple regression equation was calculated which predicts the caloric value of TDN, using % digestible protein as the independent variable:

Calories per gram TDN$=4.343+0.0199 \times$ % digestible protein

Coefficients of determinations were calculated between the experimentally determined DE values and each of its corresponding values. These coefficients were predicted with either one of the two methods in order to determine whether or not the regression equation gives a better estimate of experimentally determined DE values than does the constant derived from the average of roughages and mixed rations. The determination coefficients between the experimentally determined DE values and their corresponding values as calculated by Swift's (1957a) average value was quite high ($r^2=0.91$). Hence, when using TDN alone 91% of the variability of the DE value is explained. In accord with expectations, a higher degree of correlation was found between experimentally determined DE values and their corresponding values as calculated by the regression equation, the coefficient of determination being 0.96. Consequently, a prediction of DE, which also considers digestible protein, explains 56% ($5\div9=56\%$) of the remaining variability. Four percent of the original variability remains unexplained, a large part of which may be explained as unavoidable experimental error.

In practice, the caloric value of TDN in roughages may be calculated from the simple regression equation or by referring to table 1.

It appears that the inclusion of digestible protein in the prediction of DE values is justified because it eliminates over half of the variability remaining from an average TDN-DE conversion factor which considers TDN only. Many experiments are being conducted at the present time in which both TDN and DE are determined from one and the same digestion trial. When these data are available, an adjustment of the constants in the

regression equation may further improve the prediction of DE values from the experimentally determined TDN and digestible protein figures.

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EFFECTS OF A SIMULATED SNOWBOUND STRESS CONDITION ON EWES [1]

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IT has been observed by ranchers who have had experience with snowbound sheep and cattle that some animals perish after being given an emergency feeding of alfalfa hay. It is also believed that losses are fewer if a high carbohydrate feed, such as corn, is supplied to snowbound sheep. These observations suggest that water intake in the form of snow may be inadequate when snowbound ruminants are given a high protein emergency feed. It has been shown with dogs that protein food decreases the period of survival without water whereas sucrose or glucose prolong survival (Danowski *et al.*, 1944). Clark and Quin (1949) found that alfalfa hay consumption by Merino wethers was reduced by limiting water intake, but consumption of grass hay was not. Ritzman and Benedict (1924) observed that water intake of steers was higher on a high protein fattening ration than on a high carbohydrate fattening ration.

A high fat feed might be desirable for emergency feeding of snowbound animals. Caloric value of the feed would be high, and the oxidation of fat would give more metabolic water than oxidation of carbohydrate.

In the experiment reported here, the response of pregnant ewes under a simulated snowbound condition to a high carbohydrate, a high fat and a high protein emergency feed was studied.

Procedure

Seventy-two aged range ewes were purchased in December, 1956. Nothing was known of the past history of the ewes, except that they were bred to lamb in March and April, 1957. Those which were pregnant were, therefore, in late pregnancy while snowbound. The ewes were divided into a poor and a good condition group. Ewes in the poor condition group averaged 136 lb. in body weight. Those in the good condition group averaged 144 lb. For 43 days the ewes in the poor group were fed to maintain body weight while those in the good group were fed to gain weight. Each group was then divided into a group which received only snow as a source of water and a group which had access to water while penned on snow. The four groups were then fasted 6 days.

After fasting, each group was divided into three groups, six ewes each, and placed on emergency feed. The feeds were (a) alfalfa hay 75%, cotton-

[1] This study conducted in cooperation with Western Region Research Project W-46, The Effects of Environmental Stresses on Range Cattle and Sheep Production.
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seed meal 25%; (b) grass hay 75%, barley 25%; and, (c) grass hay 85%, inedible animal fat 15%. Under the conditions of this experiment, these three feeds constitute a high protein, a high carbohydrate and a high fat feed, respectively. The ewes offered the grass hay-animal fat feed during the emergency feeding period refused to eat and after 7 days were placed on alfalfa hay. Clean snow was available at all times for those groups which had only snow as a source of water.

Air temperatures ranged from —0.1 to 50.0° F. while the ewes were snowbound. Average temperature was 26.2° F. There was a total of 0.30 in. of precipitation in the form of snow. Average wind velocity was 2.14 mph.

Jugular blood was drawn from each ewe into sodium citrate at the beginning and end of fasting, and at days 7 and 14 of the emergency feeding period. Bleedings were made between 10 a.m. and 3 p.m. Body weights and rectal temperatures were taken at the same time.

As indices of hemoconcentration, blood hematocrit and specific gravity determinations were made. As an index of stress, direct blood eosinophil counts were made according to the method of Speirs and Meyer (1949). It was found that 16.3% acetone in the phloxine diluent disrupted all cells except eosinophils.

Plasma ketone bodies were determined by a modification of the method of Michaels *et al.* (1951). Acetoacetic and β-hydroxybutyric acids were converted to acetone by boiling with sulfuric acid and potassium dichromate within a 20 ml. blood serum tube sealed with an apron type stopper. The acetone phenylhydrazone was then developed and taken up in carbon tetrachloride within the same serum tube sealed with a cork. The carbon tetrachloride fraction was finally transferred to a cuvette for photometry.

Data on groups within periods were subjected to analysis of variance. Between period differences were tested for significance by the "t" test.

Results

There was no mortality during starvation or the emergency feeding period. The fasting ewes appeared to be looking for feed for the first 2 or 3 days. After this, they became listless and appeared to be conserving themselves. Ewes were seen ruminating, urninating and defecating at the end of the starvation period. Feces appeared abnormal. Pellets were not well formed. Fecal material was finely ground and often covered with mucus. Impaired vision was a common characteristic. Nine ewes required treatment with molasses drench or intravenous dextrose before they would begin eating following fasting. Six of these were ewes which had been fed to good condition before fasting. Surprisingly, the ewes did not eat greedily when offered feed after fasting. The snow, which was wet and loose, was readily consumed by the snow groups during the emergency feeding period.

The 24 ewes offered the 15% animal fat emergency feed ate very little

during the week it was offered. These sheep would have perished had the feed not been changed. Feed consumption for all groups was doubled during the second week of emergency feeding. Groups having access to water consumed 1043 lb. of feed, while those having only snow consumed 930 lb. during the emergency feeding.

During the 6-day fast, ewes lost an average of 13.2±0.5 lb. or 9.0% of body weight. The good condition groups lost more weight than the poor groups. Ewes having only snow as a source of water did not lose more than those having access to water. During the first week of emergency feeding, ewes gained an average of 7.6±0.6 lb. There were no group differences in body weight at this time. During the second week of emergency feeding, the ewes recovered their original prefast weight. Once again the ewes in the good condition groups weighed more than those in the poor condition groups. At this time also, the ewes having access to water averaged 146.9±2.6 lb. while those on snow averaged 139±2.6 lb.

Rectal temperatures increased slightly, but significantly during fasting and then remained the same during the emergency feeding period. At 14 days postfast, good condition ewes had significantly lower body temperatures than poor condition ewes (102.5±0.19 *vs.* 103.5±0.20° F.). Ewes having access to water had lower temperatures than those having only snow as a source of water (102.7±0.17 *vs.* 103.3±0.21° F.).

Hematocrit values were higher on good condition ewes than on poor condition ewes at the end of the conditioning period. There was evidence of hemoconcentration on all groups during the fasting period. Hematocrit values increased from 35.4±0.53 to 37.2±0.48%. During the first 7 days of emergency feeding, hematocrit values decreased on ewes offered the high carbohydrate and high protein feeds. Those offered the animal fat feed showed further hemoconcentration. After 14 days of emergency feeding, hematocrit values on good condition ewes were again higher than those of poor condition ewes (37.1±0.47 *vs.* 34.1±0.62%). There was no evidence that source of water affected the hematocrit values.

Ewes fed to gain weight during the prefast period had higher blood specific gravities than those fed to maintain weight. This difference disappeared during starvation, and reappeared after 7 days of emergency feeding. Source of water had no effect on blood specific gravity. Unlike the hematocrit values, fasting did not alter blood specific gravity. However, blood specific gravities dropped significantly after 14 days of emergency feeding.

There were no significant group differences in concentrations of circulating eosinophils at any of the four bleedings. If there were group differences in the relative degrees of stress, these were not reflected in eosinophil counts. Fasting caused a significant eosinopenia (table 1). Eosinophils were decreased 23.4% after 6 days of fasting. On day 7 of the emergency feeding period, there was a still greater eosinopenia, with counts decreased 57.5%

from prefast levels. By the end of the emergency feeding period, eosinophils had increased significantly above day-7 levels. Counts were still below prefast levels, however.

After the emergency feeding period all ewes were fed liberally on alfalfa hay and barley. Molasses was provided *ad lib*. The ewes were again bled between 80 and 84 days after the simulated snowbound fast. All except one pregnant ewe had lambed. There were six dry ewes. Circulating eosinophils were slightly, but not significantly above initial counts.

The predominant ketone body in the plasma was β-hydroxybutyric acid. Amounts ranged from 0.00 to 49.48 mg. %. The highest concentration of acetoacetic acid plus acetone was 4.36 mg. %. In 42% of the plasma samples, no acetone or acetoacetic acid was detected. There were no group differences in plasma ketones at the beginning of the simulated snowbound

TABLE 1. EFFECT OF FASTING AND EMERGENCY FEEDING ON CIRCULATING EOSINOPHILS OF 72 MATURE EWES PENNED ON SNOW

Bleeding		Eosinophils per mm^3		
No.	Time	Mean	Difference	Mean difference[a]
1	Prefast	261	2—1[b]	−61+18.3**
2	After 6 days fast	200	3—2	−89±17.4**
3	Day 7, emergency feed	111	4—3	+97±15.3**
4	Day 14, emergency feed	208	4—1	−53±21.1**
5	80 to 84 days postfast	295	5—1	+34±34.6

[a] Mean difference±standard error of difference.
[b] Mean for bleeding no. 2 minus mean for bleeding no. 1.
** $P<0.01$.

condition. As shown in figure 1, ketone bodies increased significantly from 3.20±0.16 to 9.54±0.47 mg. % during the fasting period. There were no significant group differences in ketones at the end of fasting, however poor condition ewes averaged 8.79±0.64 mg. % while good condition ewes averaged 10.29±0.68 mg. %. Total plasma ketones decreased significantly, to an average of 7.71±0.69 mg. %, after one week of emergency feeding. There were group differences in ketones at this time. Ewes given the high protein emergency feed with free access to water had 3.84±0.29 mg. % ketones, while those having only snow as a source of water had 6.23±1.05 mg. % ketones. Ewes fed the high carbohydrate feed with only snow had 3.25±0.30 mg. % ketones. After the second week of emergency feeding, plasma ketones had further decreased to 4.38±0.69 mg. %. There were no group differences at this time. The recovery from ketonemia appears to be faster than the recovery from the stress of fasting as indicated by circulating eosinophils (fig. 1).

Plasma ketone bodies were determined on the 66 surviving ewes 80 to 84 days postfast. Most of the ewes were suckling lambs at this time. Average

plasma ketones was 6.05±0.44 mg. %. This is significantly higher than values found initially and after 2 weeks of emergency feeding.

Discussion

From this study, it appears that the ewes fed high protein emergency feed and having only snow as a source of water were not seriously affected. However, the snow available for these ewes was loose and wet. The type of snow which would be available to snowbound animals in a severe blizzard might not be as easily consumed. Also, if the fasting ewes had been offered unlimited high protein feed before they became listless, they may have eaten greedily. Under such a condition, snow might not be an adequate

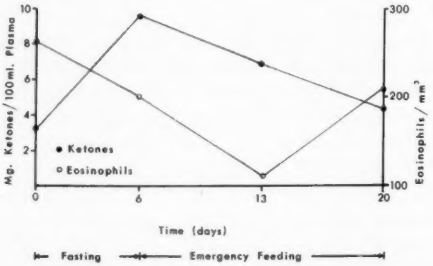

Figure 1. Changes in plasma ketone bodies and blood eosinophils of pregnant ewes under a simulated snowbound, fasting condition and during emergency feeding.

source of water, especially if it were hard or dry. Although not tested statistically, group feed consumption was lower when this loose, wet snow was the source of water. Also, the ewes which had access to water during the emergency feeding period regained their prefast body weight sooner than those which had only snow. Fasting itself caused anhydremia as shown by increased hematocrit values. However, the return of hematocrit values to prefasting levels was as rapid in ewes having only snow as a source of water as it was in those having access to water. The type of feed the ewes consumed during the emergency feeding period had no effect on hemoconcentration, except that those ewes which were offered the 15% animal fat feed ate very little and so the anhydremia persisted.

The only other evidence from this study that water intake from snow may be inadequate was the higher plasma ketone values found on the high protein feed when ewes had only snow for water. It is doubtful if the 6.23 mg. % found with these ewes is abnormal. Sampson and Boley (1940) state that levels of 7 to 10 mg. % blood ketone bodies are indicative of subclinical ketosis.

It is apparent that ketosis would be a major problem with snowbound ewes. Impaired vision may make it difficult for ketotic ewes to find feed even if it was dropped close by. Many ewes (12.5% in this study) would not eat after the emergency feed was provided. Fortunately, the ketosis appears to be simple, fasting ketosis and not the primary or hypocortical ketosis as described by Shaw (1956) for dairy cattle. Response to molasses drench or intravenous dextrose was prompt. Lambing percentage was 140 and most lambs appeared vigorous.

It is interesting that six of the nine ewes which required feeding after the fast were from the good condition group. The good condition ewes also had somewhat higher plasma ketone body values. Clark (1943) has reported that when fat ewes were placed on a semi-starvation diet, ketosis developed. The poorer the condition of the ewes the more likelihood there was of their surviving for a long period on the very poor diet.

It was surprising in this study that some of the pregnant ewes did not show abnormally high plasma ketone levels after the week of starvation. Thomson (1956) presented limited data on daily blood ketones in ewes which died with pregnancy toxemia. From his study, it appears that ketotic ewes may have low blood ketones just before death.

Eosinopenia can be produced by a number of stresses, such as handling, in mice (Spiers and Meyer, 1949); chronic exposure to cold, in mice (Louch, *et al.*, 1953); fasting, in rats (Butler and Morgan, 1953); parturition, in cows (Merrill and Smith, 1954); and, parturient paresis in cows (Smith and Merrill, 1954). Shaw *et al.*, (1952) report that eosinophil levels in ketotic cows vary from normal to high, but this is preceded by a low eosinophil level. In the present study, ewes developed a significant eosinopenia when subjected to starvation stress. Recovery from this stress was slow as shown by the significant eosinopenia after 2 weeks of emergency feeding. Approaching parturition probably added to the starvation stress, although the changes in circulating eosinophils of six dry ewes paralleled those of the pregnant ewes. Variation among the ewes in eosinophil counts was high. For example, prefast counts ranged from 40 to 1030 eosinophils per mm^3, with a mean count of 261 and standard deviation of 17. Some ewes, while showing the general trend of eosinopenia and recovery, tended to have characteristically low or high counts.

Summary and Conclusions

It was not possible to demonstrate that a high protein emergency feed (75% alfalfa hay, 25% cottonseed meal) would be harmful to the recovery of starving, snowbound, pregnant ewes. A high carbohydrate feed (75% grass hay, 25% barley) was a satisfactory emergency feed. The fasted ewes would not eat a feed of 15% inedible animal and 85% grass hay, although this feed was consumed when offered before the fasting period.

The stress of the simulated snowbound condition was reflected in a

pronounced eosinopenia. With emergency feeding, there was a slow recovery from the eosinopenia of starvation.

Snowbound, pregnant ewes developed visible symptoms of ketosis and elevated plasma ketone bodies. Recovery was prompt in most ewes when emergency feed was supplied. However, some ewes (12.5%) required force feeding with soluble carbohydrate before they would eat following starvation. Plasma ketone bodies were found to be higher in the ewes when lactating than at the end of the prefasting, conditioning period.

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OATS AS REPLACEMENT FOR CORN IN COMPLETE MIXED RATIONS FOR GROWING-FINISHING SWINE

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RECOMMENDATIONS for incorporation of oats in rations for swine have been based largely on feeding trials conducted 15 to 20 years ago. Many investigations have demonstrated that the fibrous nature of oats renders them inferior to corn for swine. However, Carroll *et al.* (1937) reported results of an extensive study and concluded that oats could be fed to growing-finishing swine to the extent of nearly one-half the ration for 60- and 70-lb. pigs without appreciably affecting growth rate, although feed required per pound of gain increased slightly as the percentage of oats increased. Robison (1939) found that ground oats had a feed value of approximately 79% that of corn when fed as the only grain in drylot, and 82% when fed as one-fourth of the grain in the ration on pasture.

Carroll *et al.* (1937) also suggested that any method of preparation that made the hulls less noticeable increased palatability of oats for pigs. Crampton and Bell (1946) reported that a fine grind was more advantageous than a medium or coarse grind because the physical identity of the hull was more completely destroyed and the product was more acceptable to the pig.

A comparison of rations used and performances obtained by Carroll *et al.* (1937) with those of current feeding trials reveals marked differences. Oats in present-day, high-energy rations would presumably show a different effect than in the former rations. Further, the quality of oats, in general, has also changed and varieties currently produced may differ nutritionally from those of 15 to 20 years ago.

The tests reported herein were designed to evaluate finely ground oats as a replacement for ground yellow corn in complete mixed rations for growing-finishing swine.

Experimental

Five experiments were conducted to determine the effect of different levels of oats in rations on pig performance. On drylot, each lot of pigs was confined to a shaded concrete-floor pen, 7′×14′, with a portable house, 6′×7½′, adjacent to each pen. On pasture, each lot of pigs was confined to a one-acre plot of ladino clover-alfalfa. A portable shade, 7′×14′, provided adequate protection from the sun. In all experiments the rations were

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self-fed and, except when freezing weather dictated twice-a-day hand watering, water was available *ad libitum*.

Ninety-six pigs averaging approximately 100 lb. in weight were used in each of the first two experiments. Breeds represented were Duroc, Hampshire, Yorkshire, and crosses of these three. In experiment 1 (drylot) outcome groups of eight pigs each were formed on the basis of breed, weight, and condition, and randomly divided among treatments. In experiment 2 (drylot and pasture) outcome groups were of four pigs each, the groups paired according to weight and randomly assigned to drylot or pasture, and the pigs randomly divided among the ration treatments.

Weanling pigs were used in experiments 3 and 4, the former involving 48 Duroc and Yorkshire pigs on pasture and the latter 40 crossbred pigs on drylot. Outcome groups of four pigs each were randomly divided among the treatments. They were on test until the average weight was approximately 100 lb.

TABLE 1. COMPOSITION OF DIETS

Ingredient	Percent
Ground yellow corn Finely ground oats Solvent soybean oil meal [a]	96.5
Vitamin mix [b]	0.1
Antibiotic-B_{12} mix [c]	0.5
Dicalcium phosphate	1.5
Ground limestone	0.75
Trace mineral mix [d]	0.1
Iodized salt [d]	0.5

[a] Ratios were adjusted to maintain the same calculated crude protein level in rations within each experiment. Oats were added at levels of 0, 33, 66 and 100% of the grain in rations of experiments 1 and 2; 0, 10, 20 and 40% in experiments 3 and 4 and 0, 20, and 40% in experiment 5.

[b] Contained, grams per lb.: riboflavin 1, calcium pantothenate 2, niacin 7, choline chloride (25%) 160, irradiated yeast (9000 i.u. per gm.) 10, vitamin A acetate (250,000 i.u. per gm.) 7.5 and solvent soybean oil meal 267.

[c] Contained, per lb.: 1.8 gm. chlortetracycline hydrochloride and 1.8 mg. of vitamin B_{12} activity.

[d] Contained, grams per lb.: $MgCO_3$ 31, $FeSO_4$ 90, $MnSO_4 \cdot H_2O$ 27, $CoCl_2 \cdot 6H_2O$ 9, $CuSO_4$ 9, NaF 2, $ZnCO_4$ 4, and KI 4. In experiments 3, 4 and 5 trace elements were provided by trace-mineralized salt.

In experiment 5, oats of two different test weights were compared for their feeding value for pigs averaging approximately 60 lb. in weight. Forty-eight pigs were formed into outcome groups of six pigs each and randomly divided among treatments on drylot.

In all tests individual pig gains and lot feed consumption were determined every 14th day. The data were subjected to analysis of variance (Snedecor 1946).

The ingredients used in the diets fed are shown in table 1.

Results

The results of experiment 1 are shown in table 2. It was intended to evaluate the effect of pelleting upon utilization of the rations fed, but the comparison with meal rations is imperfect since only an estimated 50 and 35% of the pellets in the 60 and 95% oats rations, respectively, were still

TABLE 2. SUMMARY OF RESULTS OF EXPERIMENT 1. (WINTER 1955–56)[a, b]

Items	Percent oats				Average
	0	29	60	95	
Average daily gain, lb.					
Meal rations	1.76	1.52	1.37	1.21	1.47
Pellet rations	1.77	1.58	1.39	1.30	1.51
Average	1.77	1.55	1.38	1.26	
Feed per lb. gain, lb.					
Meal rations	3.67	4.25	4.33	4.74	4.25
Pellet rations	3.68	4.16	4.56	4.81	4.30
Average	3.67	4.20	4.44	4.77	
Average daily feed, lb.					
Meal rations	6.44	6.47	5.93	5.72	6.14
Pellet rations	6.51	6.58	6.32	6.27	6.42
Average	6.48	6.52	6.12	5.99	
Ration analysis, %					
Crude protein					
Meal	13.2	13.1	12.4	11.6	
Pellet	12.7	13.1	12.8	12.4	
Crude fiber					
Meal	2.8	4.9	6.7	8.1	
Pellet	2.8	4.8	6.5	8.5	

[a] Average initial weight per pig was approximately 97 lb.
[b] These data cover the 40 days required for the first lot of pigs to reach 200 lb. Each figure represents an average performance of 12 pigs.

intact when the feed was made available to the pigs. As the level of oats in the ration increased, average daily gains decreased and the feed required per pound of gain increased. Although no apparent nutritional effect was produced from the pelleting process there was a trend toward increased daily consumption of pelleted rations above meal rations as the percent of oats in the rations increased.

Table 3 shows the results of experiment 2. In contrast to experiment 1, including 29% oats in the ration did not materially affect daily gain and feed efficiency on drylot while the 60 and 95% levels markedly reduced performance. However, on pasture the decreases in gain and feed efficiency were about the same for 29% as for the higher levels of oats. Daily feed consumption averaged 0.81 lb. less on pasture than in drylot, and, except for the 29% oats ration, the pigs on pasture required less feed per pound of gain.

TABLE 3. SUMMARY OF RESULTS OF EXPERIMENT 2. (SUMMER, 1956)[a, b]

Items	Percent oats				Average
	0	29	60	95	
Average daily gain, lb.					
Drylot	1.78	1.75	1.59	1.35	1.62
Pasture	1.70	1.39	1.37	1.38	1.46
Average	1.74	1.57	1.48	1.37	
Feed per lb. gain, lb.					
Drylot	3.80	3.88	4.21	4.60	4.12
Pasture	3.55	4.24	4.04	4.17	4.00
Average	3.67	4.06	4.12	4.38	
Average daily feed, lb.					
Drylot	6.76	6.78	6.71	6.23	6.62
Pasture	6.04	5.90	5.53	5.77	5.81
Average	6.40	6.34	6.12	6.00	
Ration analysis, %					
Crude protein	13.4	13.4	13.4	12.9	
Crude fiber	2.5	4.5	7.2	10.3	

[a] Average initial weight per pig was approximately 106 lb.
[b] These data cover the 56 days required for the first lot of pigs to reach 200 lb. Each figure represents an average performance of 12 pigs.

TABLE 4. ANALYSES OF VARIANCE OF EXPERIMENT 1 AND 2

Source of variance	Mean squares		Mean squares	
	d.f.	Av. daily gain	d.f.	Av. daily feed	Feed per lb. gain
Exp. 1					
Levels (L)	3	1.1967***	3	0.2737	0.8551**
Linear 1[a]		3.5501***			
Dev. 2		0.0200			
Ration Form (F)	1	0.0376	1	0.3136	1.0138
Replicate (R)	1	0.0580	1	1.5750*	0.2576
L x F	3	0.0101	3	0.0527	0.0179
Groups in R	10	0.3433**			
Remainder	76[b]	0.0618	7	0.2242	0.0684
Exp. 2					
Levels (L)	3	0.5525***	3	0.1395	0.3689
Linear 1[c]		1.6031**			
Dev. 2		0.0543			
Pasture vs. Drylot (D)		0.4732**	1	2.6325	0.0060
Replicate (R)	1	0.0043	1	0.0770	0.0360
Outcome Groups (G)	20	0.0849			
L x D	3	0.1569*	3	0.0902	0.2449
R x D	1	0.0744	1	0.0163	0.0003
R x L	3	0.1065	3	0.0432	0.1443
R x L x D	3	0.0855	3	0.5164	0.0919
Remainder	60	0.0647			

[a] $b = -0.52 \pm 0.07$ lb. per day with change from 0 to 100% oats as grain in ration.
[b] One degree of freedom was lost because of a missing value.
[c] $b = -0.35 \pm 0.07$ lb. per day with change from 0 to 100% oats as grain in ration.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

The analyses of variance of experiments 1 and 2 are shown in table 4. In experiment 1 there was a significant ($P<0.001$) linear relationship between oats level and average daily gain. In experiment 2 the total average gains show a significant ($P<0.001$) linear relationship and there was a significant ($P<0.01$) interaction of location (pasture or drylot) and level of oats in the diet. Oats level significantly ($P<0.01$) affected the amount of feed required per pound of gain in experiment 1.

Since the first two experiments demonstrated the inability of the finishing pig to utilize efficiently the oats rations, experiments 3 and 4,

TABLE 5. RESULTS OF EXPERIMENTS 3[a] AND 4[a]

Items	Percent oats				Average
	0	8	16	32	
Average daily gain, lb.					
Exp. 3 (pasture)[b]	1.28	1.15	1.09	1.18	1.17
Exp. 4 (drylot)[c]	1.30	1.23	1.23	1.21	1.24
Average	1.29	1.19	1.16	1.19	
Feed per lb. gain, lb.					
Exp. 3 (pasture)	2.76	2.66	3.17	2.84	2.86
Exp. 4 (drylot)	2.85	3.07	2.98	2.99	2.97
Average	2.80	2.86	3.07	2.91	
Average daily feed, lb.					
Exp. 3 (pasture)	3.53	3.06	3.45	3.35	3.35
Exp. 4 (drylot)	3.73	3.79	3.68	3.62	3.70
Average	3.63	3.42	3.56	3.48	
Ration analysis, %					
Crude protein	15.2	15.5	15.5	15.6	
Crude fiber	2.7	3.1	3.6	4.8	

[a] Average initial weight of 32.8 and 36.0 lb. for experiments 3 and 4, respectively. Average final weights were approximately 100 lb.
[b] Each figure represents average performance of 12 pigs.
[c] Each figure represents average performance of 10 pigs.

using weanling pigs, were designed to study lower levels of oats. The young growing pig should be even more limited than the 100 lb. pig in utilizing high-fiber rations.

The results are shown in table 5. In both trials most rapid gains were realized on the control rations, and the reduction in growth rate within each experiment was approximately the same for all levels of oats. The analyses of variance, table 6, show that the daily gains on pasture were significantly affected by oats level. Although there was no significant difference in feed required per pound of gain due to levels of oats, with the exception of the 8% oats ration on pasture, including oats in the rations increased the quantity of feed required per pound of gain.

Although seasonal effects must not be overlooked, it is possible that the quality of oats used in experiment 1 and experiment 2 would help explain the differences in response to oats levels fed on drylot. Thus, experiment 5

TABLE 6. ANALYSES OF VARIANCE OF EXPERIMENTS 3 AND 4

Source of variance	Mean squares		Mean squares		
	d.f.	Av. daily gain	d.f.	Av. daily feed	Feed per lb. gain
Exp. 3 (Pasture)					
Levels (L)	3	0.0702***	3	0.0826	0.0984
Replicate (R)	1	0.4052***	1	1.0654*	0.0578
R x L	3	0.0072	3	0.0390	0.0157
Remainder	30	0.0045			
Total	47		7		
Exp. 4 (Drylot)					
Levels (L)	3	0.0465	3	0.0826	0.0168
Replicate (R)	1	0.3940	1	1.0658*	0.1012
Outcome groups	10	0.1586***			
R x L	3	0.1067	3	0.0388	0.0116
Outcome groups	8	0.0859			
Remainder	20	0.0477			
Total	35[a]		7		

[a] Four degrees of freedom lost because of missing values.
* $P<0.05$.
*** $P<0.001$.

was conducted with oats of 24- and 32-lb. test weights. Further, the corn-soybean oil meal ration was diluted with 10% oat hulls so the crude fiber content would be comparable to the 40% oats (32-lb.) ration. The results are shown in table 7.

The most rapid and efficient gains were obtained with the corn-soybean oil meal diet. For the 24- and 32-lb. test weight oats rations, the daily gains were essentially the same, but pigs receiving the former required more feed per pound of gain. The inclusion of 10% oat hulls in the corn-soybean oil meal ration resulted in gains and feed efficiency comparable to the ration containing 40% of the 32-pound test-weight oats. Average daily feed consumption was lowest in the 10% oat hulls group.

TABLE 7. RESULTS OF EXPERIMENT 5[a]

Items	Percent oats and test weight					10% oat[b] hulls
	0	20	40	20	40	
	—	24 lb.		32 lb.		
Average daily gain, lb.	1.72	1.62	1.40	1.64	1.46	1.41
Feed per lb., gain	2.95	3.11	3.49	3.01	3.26	3.30
Av. daily feed, lb.	5.06	5.03	4.90	4.94	4.75	4.66
Calculated crude fiber, %	3.08	4.90	6.72	4.90	6.72	6.57

[a] Eight pigs per lot. Average initial weight was approximately 60 lb. Test was of 5 weeks duration.
[b] Ten percent of hulls were used to bring the crude fiber content of the basal (Corn-SBOM) ration up to that in the 40% oats rations.

The analysis of variance in table 8 show a significant ($P<0.01$) difference among treatments for average daily gains.

Discussion

In this study, replacement of various quantities of corn with oats did not enhance the nutritive value of rations for growing-finishing swine. The extent to which oats could replace corn without adversely affecting growth rate and feed efficiency was determined largely by size of animal and quality of oats. Reduction of growth rate on drylot appeared to reflect the quality as well as quantity of oats in the ration. On pasture all levels of oats fed had nearly the same detrimental effect. This latter condition presumably reflected free-choice consumption of forage, since the metabolizable energy per pound of total feed consumed would be affected by the fiber content of the combined selection of forage and mixed ration.

TABLE 8. ANALYSIS OF VARIANCE OF EXPERIMENT 5

Source of variance	d.f.	Mean squares Av. daily gains
Treatment	5	0.1416**
Outcome groups	7	0.0621*
Remainder	35	0.0208

* $P<0.05$.
** $P<0.01$.

That the total digestible nutrients (TDN) in the rations were largely responsible for difference in performance was subsequently shown by Jensen *et al.* (1957) when the inhibitory effect of oat hulls in a corn-soybean oil meal ration was overcome by equating ration TDN values by the addition of corn oil.

The calculated TDN values for the 0 and 95% oats rations were, respectively, 76.5% and 58.9%. Thus, replacing all the corn with oats reduced the TDN by 23%. In each test the lowest daily feed consumption was on the highest level of oats. The pig has a limited ability to utilize crude fiber (Crampton and Bell 1946; Forbes and Hamilton 1952) and there was no indication that the pigs attempted to eat more feed to compensate for the lower TDN value. In contrast, Axelsson and Ericksson (1953) reported a slight increase in daily feed intake with increased crude fiber level. However, the apparent increased consumption did not compensate for the decreased total metabolizable energy value of the diets. They further suggested crude fiber levels (calculated on a dry-matter basis) of 6.57% and 7.26% as optimum for rate of gain and feed efficiency, respectively. In the present report, however, crude fiber levels (on dry-matter basis) above the approximate 3.0% in the basal rations did not improve gain or efficiency, while levels of only approximately 5.3% on drylot and

3.5% on pasture apparently inhibited performance. The data in tables 2 and 3 suggest, however, that crude fiber values *per se* do not define the feeding quality of the rations since more rapid gains were obtained in drylot on 7.2 and 10.3% crude fiber rations fed in experiment 2 than on 6.5 but 8.5% crude fiber rations fed in experiment 1.

A non-nutritional disadvantage of the high oats rations was the bulky nature of the mixture. This physical characteristic prevented an even flow of feed in the self-feeders and necessitated daily attention to ensure feed being available to the pigs. Presumably complete pelleting would largely alleviate this problem since the incomplete pelleting in the tests reported here reduced bulkiness and associated feeder difficulties to an appreciable extent.

Recommendations of specific quantities of oats in rations for swine must of necessity be general owing to the extreme variation in quality of grain which may be encountered. For instance, oats of 16 lb. test weight per bushel (standard test weight, 32 lb.) would have a high hull percentage and low feeding value for the pig.

On the basis of the results discussed, oats should not generally replace corn in a corn-soybean oil meal type ration if maximum growth rate and feed efficiency are desired.

Summary

Five experiments involving 328 pigs were conducted to evaluate finely ground oats as a replacement for ground yellow corn in corn-soybean oil meal diets. One-hundred-pound pigs in drylot had gains and feed per pound of gain, respectively, of 1.77, 3.67; 1.55, 4.20; 1.38, 4.44; and 1.26, 4.77 for rations containing 0, 29, 60 and 95% oats. In a second experiment using a different source of oats, growth and feed efficiency were decreased markedly on the two higher levels but not on the 29% oats rations on drylot. On pasture, however, reductions in performance for all oats rations were similar. With weanling pigs, neither 8, 16 nor 32% oats in the rations enhanced growth rate and/or feed efficiency.

Existing differences in feed quality of oats were demonstrated by feeding oats of 24-pound and 32-pound test weights to 60-pound pigs. Compared to performance on the corn-soybean oil meal control ration, growth rates were reduced approximately the same on oats of the two test weights when fed at levels of 20 and 40%. However, more feed was required per pound of gain on the 24-pound than on the 32-pound oats ration. Including 10% oat hulls in the control ration resulted in gains and feed efficiency comparable to those obtained on the 40%, 32-pound oats ration.

Calculated total digestible nutrient (TDN) values of the rations decreased as the percent of oats increased. Variations in performance on the diets containing different levels of oats appear to reflect the TDN value of

the ration and the total TDN intake. Voluntary feed consumption was not increased to compensate for the lowered TDN value of the ration.

The variation in feed quality of currently produced oats makes it nutritionally inadvisable to recommend specific levels in rations for growing-finishing swine. Replacing corn in a corn-soybean oil meal type ration can be expected in general to reduce growth rate and feed efficiency, the degree of reduction being largely determined by percent hull of the oats and percent oats in the ration.

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THE EFFECT OF LOW-LEVEL DIETHYLSTILBESTROL IMPLANTATION, OXYTETRACYCLINE AND HYDROXYZINE ON FATTENING LAMBS

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Sherman *et al.* (1957, 1958) found that 1.2 gm. hydroxyzine per ton of total ration increased rate of gain of fattening lambs by 15%. In the same study 3 gm. Rauwolfia vomitoria per ton of feed also brought about an increased rate of gain of 16%. Andrews *et al.* (1958) reported that 0.25 mg. of reserpine per lamb daily did not increase gains significantly; however, this amount far exceeds the quantity of reserpine (14 mcg. daily) which the lambs received from Rauwolfia in the experiments of Sherman *et al.* (1958). In the experiments of Andrews *et al.*, 0.5 mg. of reserpine per lamb daily depressed gains below those of controls.

The effect of diethylstilbestrol (stilbestrol) implantation in increasing weight gains of fattening lambs is well known. The experimental data prior to July 1952 have been extensively reviewed by Sykes *et al.* (1953). Data collected since then are in agreement and also suggest that implants of 12 mg. or more per lamb are probably too high when carcass characteristics as well as rate of gain are considered.

Hale *et al.* (1957) and Jordan *et al.* (1957) reported that a 3-mg. stilbestrol implant was as effective in increasing weight gains as a 6-mg. implant. On the basis of whole grades, Jordan *et al.* (1957) observed no difference between controls and animals given 2, 3, 4, and 5 mg., respectively, but they observed that carcasses of treated lambs were lower than controls within their respective grades. They further reported less response from ewes than wethers to stilbestrol implantation. Blair *et al.* (1957) reported more response to a 3-mg. stilbestrol implant than to 6 mg. However, Menzies and Erhart (1958) reported a greater weight gain for lambs implanted with 6 mg. as compared with 3 mg. Weight gains for all lambs in Menzies' study may be considered below optimum, probably because a high-roughage ration was fed.

The experiments presented in this paper were conducted (1) to determine the value of 3 mg. and 6 mg. stilbestrol implants in fattening ewe and wether lambs, (2) to obtain additional observations on the value of the tranquilizer, hydroxyzine,[1] in a fattening lamb ration, and (3) to evaluate the antibiotic oxytetracycline [2] in fattening lamb rations.

[1] Tran-Q, Chas. Pfizer & Co., Inc.
[2] Terramycin, Chas. Pfizer & Co., Inc.

Methods and Materials

All lambs were from Texas except those of experiment 4 which were from California. Sex of lambs is indicated in the tables except as otherwise noted. The lambs received the rations shown in table 1 in the form

TABLE 1. BASAL RATIONS FED EXPERIMENTAL LAMBS

Ingredient	Experimental number			
	1	2	3	4, 5, 6[a]
Sun-cured alfalfa meal, 13%	64.9	20.0		35.0
Cottonseed hulls		20.0	35.00	
Dehydrated alfalfa meal			5.00	
Ground yellow corn	25.0	47.0	41.18	53.0
Cane molasses	10.0	10.0	10.00	10.0
Soybean oil meal		2.0	5.00	
Urea		1.0	1.00	1.0
Bone meal				1.0
Ground limestone			2.00	
Trace mineral premix			.05	
$NaH_2PO_4 \cdot H_2O$			0.75	
Vitamin A concentrate	0.1[b]		0.02	

[a] Ration no. 5 contained 15 gm. oxytetracycline per ton.
[b] 5,000 i.u. vitamin A per gm.

of 3/8-inch pellets. These and trace mineralized salt were self-fed, free-choice. During the adjustment period prior to the experimental period the lambs were maintained on a high-roughage ration formulated the same as the number 1 experimental ration except that the vitamin A concentrate was omitted. After 4 to 7 days of initial hand-feeding the lambs were self-fed. Animals were allotted at random into treatments from outcome groups based upon weight.

The lambs were vaccinated for enterotoxemia prior to the start of the experiment. Stilbestrol implantations were made under the loose skin on the jaw, except in experiments 5 and 6 in which implantations were made in the ear. All lambs were individually weighed at the start of the experiments and every 14 days thereafter. Carcasses were evaluated to the nearest one-third of a grade. Treatments and grouping are presented in table 2 together with rate of gain, feed efficiency, dressing percent and carcass grade.

Results and Discussion

Experiment 1. A 3-mg. or 6-mg. stilbestrol implant significantly increased rates of gains over controls (41% and 46% respectively). These data suggest that the 3-mg. implant is as satisfactory in increasing weight gains of wether lambs as the 6-mg. implant. Stilbestrol fed at the level of 0.625 mg. per lb. of ration (2.3 mg. per lamb per day) significantly

increased rate of gain over controls, but this was significantly less than the gains resulting from implantation.

TABLE 2. EFFECT OF STILBESTROL, OXYTETRACYCLINE AND HYDROXYZINE ON FATTENING LAMBS

Treatment no.	Treatment	No. lambs	Av. initial wt., lb.	Av. daily gain, lb.	Av. daily feed, lb.	Feed per lb. gain, lb.	Dressing % [a]	Grade [b]
Wethers		Experiment 1—69 days						
1	Control (Rep. 1)	12	67.7	0.402	3.44	8.57	45.59	8.00
2	Control (Rep. 2)	12	67.7	0.338	3.50	10.38	48.81	7.83
3	Stilb. impl., 3 mg. (Rep. 1)	12	67.7	0.526*	3.79	7.20	45.99	7.92
4	Stilb. impl., 3 mg. (Rep. 2)	12	67.9	0.515*	3.84	7.47	44.74	7.83
5	Stilb., 6 mg. implant	12	67.6	0.542*	3.65	6.74	45.71	7.50
6	Stilb., 1.25 gm./ton ration	12	67.8	0.450*	3.70	8.22	46.31	8.42
7	Oxytetracycline, 15gm./ton ration	12	69.6	0.373	3.27	8.77	46.47	7.92
8	Oxytetracycline, 15 gm.+ stilb. 1.25 gm./ton ration	12	67.8	0.510*	3.52	6.90	43.87*	7.92
Wethers		Experiment 2—70 days						
1	Control	12	68.3	0.415	3.90	9.38	47.97	9.17
2	Stilb. implant, 3 mg.	12	68.9	0.576*	3.70	6.41	47.55	8.42
3	Hydroxyzine, 2 gm./ton ration	11	69.1	0.531*	3.90	7.35	48.33	9.09
4	Oxytetracycline, 15 gm./ton ration	12	67.8	0.506*	4.08	8.07	51.41*	8.80
5	Rauwolfia vomitoria, 3 gm./ton ration	12	69.0	0.436	3.79	8.70	50.37	9.50
Ewes								
1	Control	12	62.9	0.435	3.44	7.91	50.00	9.67
2	Stilb. implant, 3 mg.	11	62.7	0.491	3.59	7.33	48.31	8.45*
3	Stilb. implant, 6 mg.	12	63.1	0.535*	3.70	6.93	48.19	8.67*
Ewes		Experiment 3—70 days						
1	Control	12	72.1	0.446	4.07	8.37	50.90	9.82
2	Oxytetracycline 15 gm./ton ration	12	72.3	0.511	4.29	8.41	49.78	10.08
		Experiment 4—83 days						
1	Control (Rep. 1)	11	69.5	0.355	2.86	8.06	51.08	9.36
2	Control (Rep. 2)	11	68.5	0.350	2.79	7.95	51.51	9.91
3	Hydroxyzine, 1.2 gm./ton ration	9	70.3	0.499*	3.64	7.29	53.41*	10.78*
4	Hydroxyzine, 2.0 gm./ton ration	11	68.7	0.411	3.21	7.81	52.08	9.91
5	Oxytetracycline, 15 gm./ton ration	11	68.3	0.444*	3.20	7.20	51.53	10.20
6	Stilb. implant, 3 mg.	11	68.6	0.450*	2.87	6.36	50.58	10.80*
Wethers		Experiment 5—42 days						
1	Control	7	107.3	0.823	....	....	46.42	8.57
2	Stilb. implant, 3 mg.	8	105.2	0.993*	....	....	45.38	8.38
Wethers		Experiment 6—63 days						
1	Control (Rep. 1)	12	76.2	0.562	3.86	6.88	49.94	11.00
2	Control (Rep. 2)	12	77.4	0.554	3.91	7.07	50.91	11.00
3	Stilb. implant, 3 mg.	12	75.7	0.715*	4.26	5.95	48.26	9.75*
4	Oxytetracycline, 15 gm./ton ration	12	79.7	0.571	4.01	7.02	49.50	10.75

* P=0.05.

[a] Based on last experimental weight and cold carcass weight, except experiment 4, where warm cracass weights are used.

[b] Numerical grade: Low choice 10, high good 9, average good 8, low good 7.

Oxytetracycline alone at the rate of 7.5 mg. per lb. of feed failed to increase rate of gain in this experiment. However, a combination of oral stilbestrol and oxytetracycline resulted in a 13% response over oral stilbestrol alone. Similar results have been reported by Jordan *et al.* (1957) from simultaneous feeding of chlortetracycline [3] and stilbestrol to fattening lambs.

Analysis of variance revealed no significant difference in carcass grade due to treatment, although the 6-mg. implant group had slightly lower numerical grades than the control. In general, carcass grades were lower for all animals than anticipated, perhaps because of the high-roughage ration.

Dressing percent based upon chilled carcass weights and last experimental live weight showed no differences except that the animals receiving oral stilbestrol plus oxytetracycline dressed lower than the control group. No explanation is available. Total shipping and yard shrink prior to slaughter based upon group weights did not differ according to treatment.

Experiment 2. In this experiment stilbestrol implantations were made with both ewes and wethers. Two lambs died early in the trial and the data have been corrected for those. For wethers, a 3-mg. stilbestrol implant brought a 39% increase in rate of gain over untreated animals. Carcasses were lowered by approximately one-third of a grade due to treatment. Oral stilbestrol increased rate of gain by 22% but also caused a slight reduction in carcass grade. Oxytetracycline, 15 gm. per ton, increased rate of gain by 22% and increased dressing percent, but had no effect upon carcass grade. Response of ewes to a 3-mg. stilbestrol implant was less than that of wethers. Jordan *et al.* (1957) reported ewe lambs require a larger implant than wethers to respond equally. Taylor *et al.* (1957) and Hale *et al.* (1956) reported ewe lambs would not respond to 1–2 mg. of stilbestrol in feed; however, Taylor *et al.* (1957) found that 3.5 mg. increased gains in one out of two trials.

Only two break joints could be broken of the 36 ewe lambs in this experiment, thus not permitting an evaluation of stilbestrol implants upon rate of maturation of ewe lambs. In ewe lambs on both levels of implant, there was a non-significant reduction in dressing percent. Carcass grades were lowered by approximately one-third grade due to treatment.

The tranquilizer, hydroxyzine, at 2.0 gm. per ton of ration (3.9 mg. per head per day), increased rate of gain by 28%. Carcass grade and dressing percent were not affected. The increase in rate of gain obtained by adding 3.0 gm. Rauwolfia vomitoria was not as large as the response observed by Sherman *et al.* (1958) in an earlier trial. However, the Rauwolfia vomitoria did improve carcass grade and increased dressing percent markedly.

[3] Aureomycin, American Cyanamid Co.

Experiment 3. The feeding of oxytetracycline at the rate of 15 gm. per ton of ration (32 mg. per lamb daily) to ewe lambs increased rate of gain by 15%. Dressing percent was slightly lower, but carcass grades tended to be improved.

Experiment 4. Shortly after the start of the experiment, it was observed that several of the lambs were suffering from a severe *Haemonchus contortus* infestation. All lambs were treated with phenothiazine and the most severely affected were removed within two weeks after the start of the experiment. The 83-day feeding period is believed to be sufficiently long to minimize any early effect of the internal parasite infestation.

No explanation is available for the difference in response obtained from the two levels of hydroxyzine. Either level of hydroxyzine improved dressing percent and carcass grade. Oxytetracycline, 15 gm. per ton (24 mg. per lamb daily), increased gain by 26% and improved carcass grade. In this experiment the 3-mg. stilbestrol improved rate of gain by 28% and significantly improved carcass grade. Dressing percent was slightly reduced by the stilbestrol implantation. The data in this trial suggest that the effective growth stimulating period of the 3-mg. stilbestrol implant is at least 83 days.

TABLE 3. SUMMARY OF EFFECT OF 3-MG. STILBESTROL IMPLANT, OXYTETRACYCLINE AND HYDROXYZINE ON RATE OF GAIN, DRESSING PER CENT AND CARCASS GRADE OF LAMBS

Treatment	No. controls	No. treated	Increase in rate of gain, %	Dressing %, diff. from control	Grade, diff. from control	Improvement in feed efficiency %
Stilbestrol, 3 mg. implant	101	78	28.1	−1.31	−0.38	19.3
Oxytetracycline, 15 gm. per ton ration	94	59	13.1	+0.18	+0.04	6.3
Hydroxyzine, 1.2–2.0 gm. per ton ration	32	31	28.9	+1.08	+0.50	11.0

Experiment 5. Heavy lambs were used in this experiment to determine a possible relationship between weight and stilbestrol implant dosage. The trial was run for 42 days, both control and implanted groups being in the same pen. The 3-mg. stilbestrol implant increased rate of gain by 21%. There was a slight reduction in dressing percent but little effect upon grade. The ration fed the lambs in this experiment contained 15 gm. oxytetracycline per ton.

Experiment 6. In experiment 6, rates of gain for the control animals were excellent. A 3-mg. stilbestrol implantation increased rate of gain by 28% but reduced dressing percent and grade. Oxytetracycline supplementation increased gains slightly (30 mg. per lamb daily), with little effect upon dressing percent or grade.

A summary of treatment effects based on pooled data of all experiments is presented in table 3. The 3-mg. stilbestrol implant increased

rate of gain by 28% but reduced dressing percentage by 1.31% and carcass grade by 0.38 unit. The reduction in grade is approximately one eighth of a government grade. Feed efficiency was improved by 19%. Seminal vesicle weight and bulbourethral gland measurements were taken on the control and stilbestrol-implanted animals in experiments 1 and 4. The results of these measurements are shown in table 4. In both experiments stilbestrol implants increased the size of these organs. In experiment 1 the organs were approximately 25% smaller in animals which received a 3-mg. implant as compared with those given 6 mg. Feed lot examination of all the 3-mg. implant groups did not show any side effects, except

TABLE 4. SEMINAL VESICLE WEIGHT AND BULBOURETHRAL GLAND DIAMETER OF WETHERS

Treatment	Seminal vesicle, wt., gm.	Bulbourethral gland diameter, mm.
	Experiment 1	
Control (Rep. 1)	0.69	8.5
Stilbestrol implant, 3 mg. (Rep. 1)	3.08*	15.4*
Stilbestrol implant, 6 mg.	4.08*	20.4*
	Experiment 4	
Control (Rep. 1)	0.22	
Control (Rep. 2)	0.35	
Stilbestrol implant, 3 mg.	1.94*	

* P=0.05.

some teat enlargement with little or no mammary gland development. It should be pointed out that no measurements were made to evaluate these factors. In this series of experiments the 3-mg. stilbestrol implant had no effect upon the break joint of wethers even though the lambs in experiments 2 and 5 were approximately one year of age at time of slaughter.

Several experiments have been reported in which fattening lambs were implanted with 6 mg. of stilbestrol; however, few direct comparisons are available between 3-mg. and 6-mg. stilbestrol implants. In the present study the responses as percent of the controls for 3-mg. implants are similar to those reported for 6-mg. implants. In experiment 1 the wether lambs implanted with 6 mg. gained slightly more than the lambs implanted with 3 mg. However, carcass grades were reduced by the 6-mg. implant when compared with the 3-mg. implant groups. Similar findings were reported by Andrews *et al.* (1958) in comparisons of 3- and 6-mg. implants. In experiment 2 ewe lambs implanted with 6 mg. outgained the group implanted with 3-mg. and had slightly higher carcass grades. Lambs ranging in weight from 63 to 105 lb. responded similarly to a 3-mg. implant, indicating that a single 3-mg. implant is sufficient to

result in a satisfactory weight gain increase within the usual weight range of feeder lambs.

These experiments indicate that a 3-mg. implant of stilbestrol is practical in effecting an economical weight gain increase in feeder lambs. In five treatment groups with oxytetracycline, weight gains were increased by 13%, dressing percent was improved by 0.18%. In one trial the oxytetracycline in combination with oral stilbestrol increased rate of gain over the stilbestrol alone by 13%.

In three treatment groups the tranquilizer, hydroxyzine, increased rate of gain by an average of 29%, dressing percentage by 1.08% and carcass grade by one-sixth of a grade. In one treatment group the Rauwolfia increased gains slightly and improved dressing percent and grade.

In this series of experiments none of the treatments caused digestive disturbances or erratic feed intake.

Summary

Six lamb feeding experiments were conducted to determine the effect on growth, feed efficiency and carcass quality of low-level diethylstilbestrol (stilbestrol) implantation, oral supplementation with the tranquilizer, hydroxyzine, and oral supplementation with the antibiotic, oxytetracycline. During the experimental period all lambs were self-fed a pelleted ration.

In six treatment groups, lambs implanted with 3 mg. of stilbestrol outgained controls by an average of 28% with a 19% average improvement in feed efficiency. There was some reduction in dressing percent and carcass grade. Implantation had no effect upon maturity as judged by break joints. The 3-mg. implant appeared to be practical in effecting an economical weight gain increase in feeder lambs. The tranquilizer, hydroxyzine, fed at the level of 1.2–2.0 gm. per ton of ration in three treatment groups increased gain by 29% with an increase in dressing percent and grade. The antibiotic, oxytetracycline, increased rate of gain in four of five trials by an average of 13% with a small increase in dressing percent but no effect upon grade.

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FECAL EXCRETION PATTERN OF CHROMIC OXIDE ADMINISTERED TO HEREFORD HEIFERS IN A COMPLETELY PELLETED RATION

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THE use of indicator techniques for determining digestibility offers the advantage of requiring less labor, equipment and time than the conventional total-collection method. On the other hand, the accuracy of the indicator method appears to be limited greatly by the sampling error which may result when "grab" sampling of feces is employed. The errors encountered when "grab" samples are taken is due to the large intra-day variation which occurs in the fecal excretion pattern of the indicator(s).

Chromic oxide (Cr_2O_3) is often used as an external indicator for digestibility studies but has been reported by various workers to exhibit a wide range of concentration in the feces at different times during a 24-hour period. It is usually given to ruminants in gelatin capsules. A wider range in the fecal concentration of chromic oxide has been reported (Brisson *et al.*, 1957; Hardison *et al.*, 1956; and Smith and Reid, 1955) when it is administered in one dose daily than when administered in two doses. The variation has been decreased even further by administering it six times daily (Brisson *et al.*, 1957), although the authors pointed out that such a schedule of administration is impractical.

The increasing use of ground and pelleted rations in livestock feeding affords an opportunity for the mixing of chromic oxide into the complete ration. By this procedure, relatively large numbers of animals can be sampled for digestibility studies without the need for special equipment. Moreover, it would appear possible that the time-concentration variation in fecal chromic oxide might be decreased.

This experiment was undertaken to study the fecal excretion pattern of chromic oxide when mixed uniformly in a completely pelleted ration fed to beef heifers.

Experimental Procedure

The experimental ration consisted of 50 parts corn and cob meal, 15 parts cottonseed meal, 25 parts grass hay and 22 parts molasses. These ingredients, plus bonemeal and salt added at about 1% of the ration, chromic oxide (Fisher, certified) at 0.5% and an adequate supplement of vitamin A were thoroughly ground, mixed together and pelleted. The

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chromic oxide was premixed with about ten times its weight of cottonseed meal before it was added to the ration.

Six Hereford heifers weighing about 500 lb. each were used. In the first trial, three heifers were group-fed *ad libitum* and three were group-fed once daily. The once-a-day animals were fed at 11:30 a.m. all the feed they would consume in about 2 hours. The heifers fed *ad libitum* also received fresh feed at 11:30 a.m. but were given slightly more than they would eat in a 24-hour period. The average feed intake of the heifers fed once daily was 12 lb. each. This amount was then fed each day for a 9-day preliminary period. During this same period the heifers fed *ad libitum* each consumed an average of 17 lb. daily. During the collection period grab samples of feces were collected from each heifer starting at noon and at 3-hour intervals thereafter for 48 hours.

In order to obtain feces samples it was necessary to drive the animals through a chute adjacent to the feeding lots. The animals often defecated at this time so that it was not necessary to take the sample rectally. From 150 to 400 gm. of wet feces were usually collected, but in two instances no feces could be obtained. Fecal samples were placed in plastic bags and stored in a refrigerator at 3° C. until they could be processed further, which was usually within 24 hours. All samples were then placed on aluminum pans and dried in a force-draft oven for 24 hours at 70° C. The dried samples were ground in a Wiley mill.

Each feces sample was analyzed for its moisture and chromic oxide content. Moisture analyses were conducted using a vacuum oven according to the recommended A.O.A.C. method. Chromic oxide was determined by the perchloric acid digestion method of Kimura and Miller (1957). Samples between 0.5 and 1.0 gm. in size were found to be sufficient for accurate analyses, when allowing a 3% difference between duplicate determinations.

During the second trial, the six heifers were again randomly assigned to two different feeding schedules. The schedules included a once-a-day limited feeding, consisting of 8 lb. of feed to each of three heifers at 11:30 a.m. daily, and a twice-a-day feeding schedule consisting of 7.5 lb. of feed to each heifer at 6 a.m. and 3 p.m. A 9-day preliminary period was followed by a 2-day schedule of sampling, as described earlier.

The heifers were individually penned during the second part of the experiment. In addition to measured feed intakes this made it possible to obtain fecal samples with a minimum of disturbance to the animals. Feces collected in this trial were immediately placed on pans and dried in the oven. Further processing of the samples was as described above.

In a later trial, chromic oxide was mixed into the ration of two sets of identical twin beef steers being fed at 8:30 a.m. and 4 p.m. The ration contained 89% orchard grass-alfalfa hay with linseed meal, soybean meal, salt, bonemeal and chromic oxide making up the remainder. The ration was ground and pelleted. Following an 8-day preliminary period,

fecal grab samples weighing from 300 to 500 gm. were collected from each steer at 9 a.m. and 3:30 p.m. daily for 8 days. The samples were placed on aluminum pans and processed according to the methods described earlier.

Results

The chromic oxide excretion patterns in the feces are shown in figure 1–3. The concentration of Cr_2O_3 in the feces at various times has been converted to the percentage of the daily mean concentration in figures 1 and 2 in order to show the magnitude of the variation. It is readily seen that there was considerable variation from the daily mean concentration

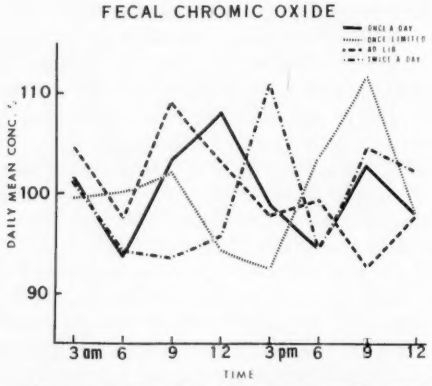

Figure 1. The relative time-concentration variation of chromic oxide in the feces of heifers fed a pelleted ration (average of six observations per treatment).

on each of the treatments. Furthermore, time-concentration variations in fecal Cr_2O_3 appeared to be influenced by the feeding schedule which is, in this case, analogous to the Cr_2O_3 administration schedule. Statistical analyses of the data showed significant ($P<0.05$) interaction between treatments and times. That is, the differences in the excretion patterns of Cr_2O_3 between the feeding schedules imposed were statistically significant.

The pattern of Cr_2O_3 excretion was quite similar for heifers fed *ad libitum* and those full-fed once daily (figure 1). Peak concentrations of Cr_2O_3 in the feces were attained at 9 a.m. and 12 a.m., respectively, on the two treatments. In general, the fecal concentration of Cr_2O_3 was higher than the daily mean before noon, except at 6 a.m., and lower after noon. The similarity in these two curves was unexpected; however, these results may be due to the fact that in both treatments the animals re-

ceived fresh feed at the same time of day (11:30 a.m.). Although the *ad libitum* fed heifers received more feed than they would eat in a 24-hour period, they were observed to eat the major portion of their daily ration at the time fresh feed was offered.

Another similarity between the animals fed once daily and those fed *ad libitum* is shown in figure 2. While an obvious diurnal pattern in Cr_2O_3 concentration of feces was found on the first day of collection, the pattern during the second day appeared to be erratic. The periodic disturbance occasioned in this study by confining the animals to the chute

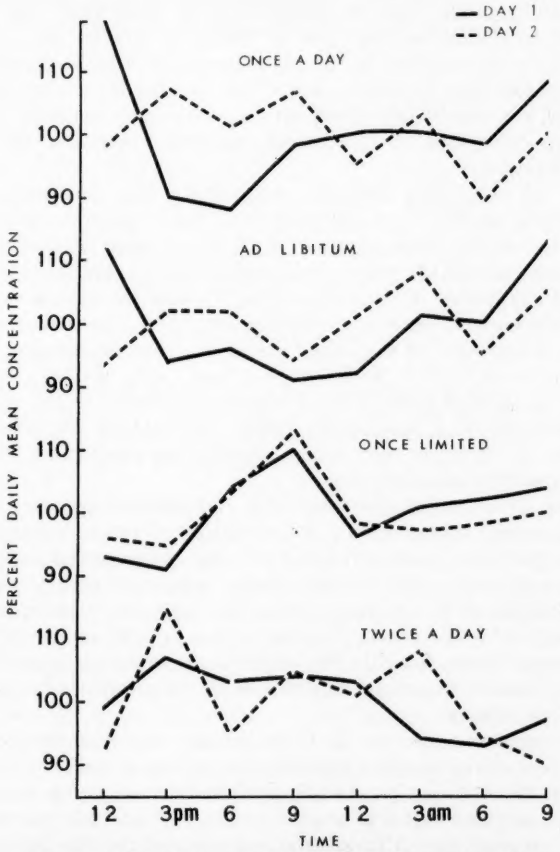

Figure 2. The fecal excretion pattern of chromic oxide on the first vs. the second day of sampling by treatments (average of three observations per day).

may have been responsible for this difference either through an effect on rate of passage of ingesta or efficiency of digestion.

Heifers fed a limited quantity of feed once daily showed a Cr_2O_3 excretion pattern which was markedly different from the other three treatments. The peak concentration of Cr_2O_3 in feces was at 9 p.m. with a low at 3 p.m. In contrast to the treatments already discussed, the excretion pattern was remarkably consistent between the two days of collection (figure 2). The fact that sampling of feces was achieved with a minimum of disturbance to the animals on this treatment may have aided in obtaining this repeatability.

It should be noted that the heifers full-fed once daily and those limited-fed once daily received feed at the same time of day, yet the peak in Cr_2O_3 concentration in the feces differed by 9 hours. Lambourne (1957) reported that in sheep given Cr_2O_3 in capsules a high level of feed intake was usually associated with an early peak concentration of fecal Cr_2O_3. The data of the present experiment indicates the same situation in cattle.

Heifers fed twice daily showed a peak in the fecal concentration of Cr_2O_3 at 3 p.m. and a low at 6 and 9 a.m. As in two of the other treatments, a smooth and obvious diurnal pattern of Cr_2O_3 excretion resulted in fecal grab samples collected the first day and a more erratic excretion pattern on the second day (figure 2). It is interesting to note the narrow range in average fecal chromic oxide concentration (93–107%) for day 1 of this treatment as compared to the same time for the other treatments.

Kameoka *et al.* (1956) have reported that Cr_2O_3 was excreted unevenly in the feces of goats, also fed twice-a-day, receiving the indicator mixed with their total concentrate ration. The authors concluded that the pattern of excretion was similar whether the concentrate containing Cr_2O_3 was fed alone or with hay.

Including all treatments, the extremes in individual observations in this experiment ranged from a low of 74% to a high of 135%. This range is much less than that reported when Cr_2O_3 was administered once daily in capsules (Putnam, 1957). Since average values are usually reported in the literature it is not known how this range compares with that found when Cr_2O_3 is given in capsules twice-a-day. However, the range of the average curves found in this experiment (figure 1) appears to be equal to or smaller than those reported in the literature for twice-a-day capsule administration.

The average concentration of Cr_2O_3 in the fecal samples collected from the two sets of identical twin steers is shown in figure 3. Samples collected in the afternoon consistently contained chromic oxide concentrations whose mean was equal to or greater than that found in the morning sample of the same day. Although the magnitude of the difference is less than that observed at the same times for heifers fed twice-a-day (figure 1), it was statistically significant ($P<0.01$). The higher concentration

of Cr_2O_3 in feces collected in the afternoon tends to confirm the type curve reported in figure 1. The steers were fed slightly later in the day than the heifers.

Discussion

While a diurnal variation in fecal Cr_2O_3 concentration has been reported when Cr_2O_3 was mixed into the complete ration of swine (Clawson, 1955; Moore, 1957) and goats (Kameoka *et al.*, 1956), the authors are not aware of any reports to this effect for cattle. The data presented here indicate that even when Cr_2O_3 is mixed into the entire ration of beef cattle it may be excreted unevenly in the feces.

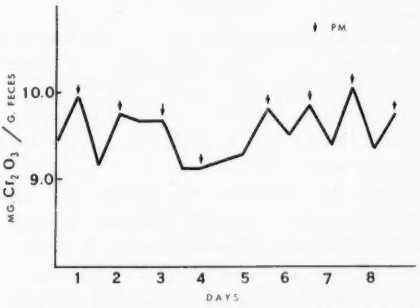

Figure 3. The average morning and afternoon concentrations of chromic oxide in the feces of four steers fed a pelleted ration twice a day.

There is some question as to why such a variation in the fecal Cr_2O_3 concentration occurs. Some investigators have stated that there is "a naturally occurring variation in the rate of chromium oxide excretion . . ." (Kane *et al.*, 1952), while others suggest that the absorption of nutrients may proceed at varying rates during a daily period (Bloom *et al.*, 1957) thus altering the Cr_2O_3 concentration. These workers would then attribute the diurnal pattern of excretion to a periodicity of psysiological processes. Another possible factor is that of separation of Cr_2O_3 from the ingesta. King and Moore (1957) have reported that Cr_2O_3 appeared to move with the fibrous constituents of the feed. These workers suggested that it may absorb onto fibrous material or may actually become lodged in pits and crevices of the fiber. On the other hand, several investigators have found that the excretion of Cr_2O_3 was not associated with the excretion of either crude fiber (Davis *et al.*, 1958; Moore, 1957) or lignin (Kane *et al.*, 1952).

The general pattern of excretion of Cr_2O_3 in the feces of animals fed the

indicator in the complete ration may be a reflection of the total time spent in the digestive tract. Theoretically, concentration of Cr_2O_3 in the rumen should be at a minimum immediately after feeding a ration containing the indicator. Likewise, ingesta leaving the rumen shortly after feeding would contain a small concentration of Cr_2O_3 compared to that leaving the rumen 24 hours after feeding. The magnitude of the differences in Cr_2O_3 concentrations existing at the region of the reticulo-omasol orifice during the day would probably be altered during the subsequent journey through the remainder of the digestive tract, but the general pattern of Cr_2O_3 excretion in the feces may be a reflection of the concentration present in ingesta leaving the rumen.

Summary

Chromic oxide (Cr_2O_3) at a level of 0.5% was mixed uniformly into a pelleted ration and fed to six Hereford heifers. The feeding schedules employed were (a) limited-fed once daily, (b) full-fed once daily, (c) full-fed twice a day and (d) *ad libitum*. Chemical analyses of feces samples collected at 3-hour intervals for 48 hours indicated that a significant time-concentration variation occurred in the fecal pattern of Cr_2O_3 excretion even though the indicator was mixed into the entire ration. Furthermore, these variations in Cr_2O_3 excretion appeared to be influenced by the feeding schedules. The magnitude of the variation in fecal Cr_2O_3 concentration during a 24-hour period encountered in this experiment would preclude the indiscriminate sampling of feces for digestion trials as regards time.

A later trial was conducted with two sets of identical twin beef steers which were fed twice-a-day a predominantly roughage diet which was ground, mixed withCr_2O_3 and pelleted. Analyses of feces samples collected in the morning and afternoon for 8 days showed Cr_2O_3 concentrations which tended to support the type of excretion pattern found in the heifers fed twice-a-day.

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EFFECT OF FEEDING METHODS ON VEAL PRODUCTION AND CARCASS QUALITY. I. RATE OF GAIN, STOMACH CAPACITY, VITAMIN A, IRON AND HEMOGLOBIN VALUES [1]

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WISCONSIN farmers marketed over 1.6 million veal calves in 1957. A large proportion of these were light weight and of inferior quality. A study (Schaars and Bray, 1950) on 613 calves reported the following percentage of each grade: Cull 7%, utility 23%, standard 33%, good 33%, choice 4% and prime less than 1%. The higher grades are usually produced by very generous feeding of whole milk. Milk fed to veal calves often returns less than if sold as fluid milk. This discourages production of high quality veal and results in marketing calves at a very young age, or feeding grain with limited amounts of milk. In either case, the finish and quality are poor as compared to full milk fed veal calves.

This project was set up to study the effect of different feeding regimens on quality, rate of gain, and returns above feed cost for veal calves.

Material and Methods

Male calves from the University herds were placed on experiment as they became available over a two-year period. They were kept in individual stalls. Seventy-four Holsteins, six Brown Swiss, and two Ayrshires were assigned in rotation to four lots. The calves nursed their dams until put on experiment the fourth day after birth. All calves received a 30-mg. capsule of chlortetracycline (Aureomycin hydrochloride) [4] daily.

The four lots were treated in the following manner. Lot 1a calves were fed twice daily in nipple pails as much mixed Holstein whole milk (av. 3.5% fat) as they would drink. These calves were fed no hay, grain, or water. Lot 1b calves were fed the same as 1a plus 240 mg. of iron as ferric pyrophosphate and 7 mg. of copper as copper sulfate daily.

Lot 2 calves were on a limited whole milk, calf starter, hay feeding plan, such as is commonly used for raising dairy calves for herd replacement. After nursing their dams for 3 days, these calves were fed milk at 9% of their body weight to 7 days of age, at 10% during the second and third weeks, 8% during the fourth, 6% during the fifth, and 4% during the sixth week. High quality alfalfa hay and water were available at

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[4] Supplied by courtesy of American Cyanamide Company, New York, N. Y.

all times. In addition, the calves were fed *ad. lib.* a starter consisting of 500 lb. ground yellow corn, 200 lb. ground oats, 300 lb. soybean oil meal, 10 lb. trace mineral salt, 20 lb. steamed bone meal, and 25 gm. irradiated yeast (4 million i.u. per lb.). Daily records of hay and starter consumption were kept.

The calves of lot 3 were fed in the same manner as lot 2 except that a milk replacer was fed instead of the milk and each calf received 25,000 i.u. of vitamin A daily. The milk replacer consisted of 55 lb. dried skim-milk, 30 lb. finely ground oat groats, 15 lb. reddog flour, and 5 gm. irradiated yeast (4 million i.u. per lb.). It was prepared for feeding by mixing at the rate of 1 lb. of the dry replacer to 7 lb. of warm water, resulting in a liquid feed containing 11.5% solids. The liquid replacer was fed from a nipple pail, twice daily, giving the calves all they would drink.

All calves were weighed daily and slaughtered at 6 weeks of age. Slaughtering procedure and carcass data are given in another paper. (Bray *et al.*, 1959). All calves were graded according to market standards before slaughter.

Liver vitamin A was determined by the method of Ames *et al.* (1954). Iron content of liver was determined by the method of Kennedy, and blood hemoglobin by the method of Wong as listed in Hawk *et al.* (1954).

At the time of slaughter, the stomach system was removed, emptied, washed and ligated between the rumen-reticulum and omasum-abomasum. The volume of each portion was measured by filling it with water of 100° F. at a static pressure of 5 feet. The capacity of each is expressed as a percentage of the total. Stomachs were weighed after cleaning, washing, draining, and removal of excess fatty tissue.

Results and Discussion

The lot fed whole milk (1a) included 23 calves. Three of these died during the experiment and data from a fourth were omitted from the analysis because of a long period of elevated temperature and poor growth. Six calves scoured slightly for an average of 2.0 days per calf.

Twenty-three calves in lot 1b were started on the experiment. Two of them were not included in the analysis because of having above normal temperature for 10 days. Eight calves had slight scours for an average of 1.2 days per calf. Calves in both lots, 1a and 1b, craved roughage and ate shavings used for bedding. The deaths in lot 1a were apparently due to irritation and blocking of the intestinal tract by shavings. Following this early experience no bedding was used for the groups fed only milk.

One of the 23 calves fed the limited whole milk, starter, and hay (lot 2) was omitted from the analysis because of a navel infection. Six calves scoured for an average of 1.7 days per calf.

Two of the 24 calves started in the milk replacer lot (lot 3) died, one was removed from the experiment because it was losing weight and was not normal, and a fourth was not included in the final analysis because of elevated temperature for 10 days. Thirteen calves had scours for an average of 1.2 days per calf. All of the calves indicated as being omitted because of prolonged elevated temperature were affected by an epidemic infection which affected most of the calves on experiment at the time.

The data were tested for significance by analysis of variance (Snedecor, 1946). Duncan's multiple range test was used where there was significance.

TABLE 1. AVERAGE GROWTH, FEED CONSUMPTION AND LIVE GRADES

Items	Lots			
	1a	1b	2	3
	Liberal milk	Liberal milk +iron +copper	Limited milk +starter +hay	Milk replacer +starter +hay
	lb.	lb.	lb.	lb.
Initial wt.	93.6	94.1	96.0	97.0
Final wt.	178.7	186.0	154.9	146.9
Gain in wt.	85.1	91.9	58.9	49.9
Daily gain	2.21	2.39	1.54**	1.31*
Total milk or liquid replacer	787.5	832.2	353.7	676.6
Milk or liquid replacer per lb. gain	9.26	9.06	6.00	13.56
Total hay	—	—	7.75	5.12
Total starter	—	—	34.48	16.38
Calculated TDN per lb. gain	1.49	1.46	1.47	1.72
Live grade[a]	19.8	19.8	15.1**	12.9**

* Significant at the 0.05 level.
** Significant at the 0.01 level.
[a] Live grade values were determined using average scores of prime=23; choice=20; good=17; standard=14; utility=11.

As shown in table 1, the whole milk plus copper and iron fed lot (1b) had the highest average daily gain (2.39 lb.) while the whole milk fed lot (1a) gained 2.21 lb. per day, both gains being significantly higher ($P<.01$) than those of the other two lots. The average daily gain of the limited whole milk fed lot (2) was 1.54 lb. which was significantly ($P<.05$) higher than the milk replacer lot (3) with an average daily gain of 1.31 lb. These gains are higher than those reported by Lassiter *et al.* (1955) and Landagora *et al.* (1957).

The average daily gain for all lots was higher than the Beltsville Growth Standard (Matthews and Fohrman, 1954). The Beltsville Growth Standard was established on calves receiving limited whole milk, hay, and starter.

Lots 1a, 1b, and 2 required 1.49, 1.46, and 1.47 lb., respectively, of calculated total digestible nutrients for each pound of gain. Lot 3 required the most TDN (1.72 lb.) per pound of gain. This is lower than that listed by Lassiter *et al.* (1955) for their chlortetracyline-fed lots. The feces of the calves of lot 3 were more watery during the six-week feeding period than of calves in the other lots.

Lots 1a and 1b graded low to average choice. This was significantly ($P<0.01$) higher than the other two lots. The calves of lot 2 graded top standard, which was significantly higher ($P<0.05$) than the low standard grading for lot 3. The calves receiving liberal whole milk gained faster and had fatter carcasses indicating the greater gain in weight

TABLE 2. STOMACH WEIGHT AND CAPACITY, VITAMIN A AND IRON OF THE LIVER AND BLOOD HEMOGLOBIN

	Lots			
Items	1a Liberal milk	1b Liberal milk +iron +copper	2 Limited milk +starter +hay	3 Milk replacer +starter +hay
Stomach wt., lb.	2.83	2.69	3.90	3.18
Stomach wt. as percent live wt.	1.58*	1.45*	2.52**	2.16**
Stomach capacity, liters	17.0	15.8	19.1	22.6
Percent stomach capacity in rumen-reticulum	35.5**	30.5**	57.0	52.4
Vitamin A per 100 gm. liver, i.u.	3166	2214	2549	19985**
Iron per 100 gm. liver, mg.	3.3	15.6**	5.3	5.4
Hemoglobin per 100 ml. blood, gm.	8.05**	15.31**	10.96	10.41

* Significant at the 0.05 level.
** Significant at the 0.01 level.

was partially accounted for as body fat. This was borne out by carcass specific gravity measurements (Bray *et al.*, 1959). There was a high correlation between live grade and carcass grade.

Calves of lot 2 had the heaviest stomachs (table 2) which as percentage of live weight (2.52%) were significantly ($P<.01$) higher than for the other three lots. In lot 3 the stomach was 2.16% of the live weight, which was significantly higher at the 1% level than lots 1a and 1b. The whole milk fed lot with iron and copper supplements (lot 1b) had the lightest stomach and as a percent of the live weight (1.45%) it was significantly ($P<0.05$) lower than lot 1a (1.58%).

Lot 2 also had the largest capacity of the rumen-reticulum expressed as percent of total stomach capacity, 57.0% compared to 52.4% for lot 3. Both lot 2 and lot 3 were significantly higher than lots 1a and 1b with 35.5% and 30.5%, respectively.

Lot 3 had the largest total stomach capacity, but lot 2 had the greatest percent of total capacity in the rumen-reticulum and the heaviest stomach.

Ten liver samples from each lot were analyzed for vitamin A. The livers from lot 3, which received 25,000 i.u. of vitamin A daily, averaged 19,985 i.u. per 100 gm. of liver. This was significantly ($P<0.01$) higher than the other three lots which did not differ statistically from one another.

Lot 2 had 15.60 mg. of iron per 100 gm. of liver. This was significantly higher at the 5% level than the other three lots. The increased iron of the livers presumably was due to the iron supplement the calves received. This group had the least storage of vitamin A in the liver, 2214 i.u. of vitamin A per 100 gm. Lot 1a had the least iron (3.3 mg.) and had 3166 i.u. of vitamin A per 100 gm. of liver. From this it appears that iron supplementation at the levels used may have a depressing effect on vitamin A storage in the liver.

Lot 1b had the highest level of hemoglobin, 15.31 gm., and lot 1a the least, 8.05 gm. per 100 ml. of blood. These were significantly different ($P<0.01$) from each other and from lot 2 with 10.96 gm. and lot 3 with 10.41 gm. of hemoglobin per 100 ml. of blood. The increased amount of hemoglobin in lot 1b apparently was due to the iron and copper supplement.

The hemoglobin content of lot 1b was higher than previously reported for young calves. The hemoglobin content of blood of lot 1a was comparable to that reported by Matrone *et al.* (1947), Eaton *et al.* (1947) and Wise *et al.* (1947), each reporting a range of 8.7 to 9.2 gm. hemoglobin per 100 ml. blood. The hemoglobin levels of the two lots receiving hay and starter were higher than reported for young calves. Rusoff and Piercy (1946) reported an average of 11.59 gm. of hemoglobin per 100 ml. of blood for mature animals.

Summary

Four methods of feeding veal calves, liberal whole milk with and without iron and copper, limited whole milk-hay-calf starter, and milk replacer-hay-starter were compared. Data are presented on 82 calves. The calves fed whole milk liberally as the sole diet made the most rapid gains and had higher live grades than those fed a milk replacer or limited whole milk ration. The average daily gains of all lots were higher than the Beltsville Growth Standard.

The weight of the stomach was significantly greater for the whole milk fed lot than for the whole milk supplemented with iron and copper lot, but for both it was lighter than for the other two lots. The rumen-reticulum capacity as percent of total stomach capacity was smaller in the whole milk fed lots. Hay and grain feeding stimulated stomach development, and resulted in more capacity in the rumen-reticulum at 6 weeks of age.

The main difference between the unsupplemented whole milk lot and the lot receiving iron and copper supplement was the significant increase in

iron of the liver and blood hemoglobin. It appears that the light pink color of the meat which is considered desirable in milk fed veal calves results from anemia.

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EFFECT OF FEEDING METHODS ON VEAL PRODUCTION AND CARCASS QUALITY. II. CARCASS GRADES, LIVER, HIDE, SPECIFIC GRAVITY, YIELD AND CHEMICAL ANALYSIS OF THE MUSCLE [1]

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MANY of the veal calves reaching our markets are light in weight and inferior in quality and finish. This situation exists because milk prices have generally discouraged production of whole milk fed calves. There is little information on the relative economy of substituting other feeds for milk and the effect of these feeds on carcass quality and yield. This experiment was designed to secure such information.

Materials and Methods

Eighty-two male calves, 74 Holstein, 6 Brown Swiss and 2 Ayrshires as born in the University herds over a 2-year period, were assigned in rotation at 4 days of age among four lots.

In lot 1a the calves were fed twice daily as much milk as they would drink from a nipple-pail. They received no hay, grain or water. Lot 1b was given whole milk in the same manner, except 240 mg. of iron and 7 mg. of copper were added daily. Lot 2 was fed limited whole milk, with calf starter, hay and water given free choice. Lot 3 was fed a milk replacer, with calf starter, hay and water available at all times. The lot 3 calves also received a capsule of vitamin A, 25,000 i.u., daily. The calves in all four lots received a 30 mg. capsule of chlortetracycline daily. The milk replacer, milk feeding schedule, starter and iron and copper compounds used are listed in Part I of this study (Niedermeier *et al.*, 1959).

At six weeks of age each calf was graded alive to the nearest 1/3 U.S.D.A. grade, slaughtered and dressed hog style. Weights of the thymus gland, liver and gall bladder were recorded at time of slaughter and hide weight after the chilling period. Dressing percentage was calculated from a 24-hour chilled carcass weight. The carcasses were also graded to the nearest 1/3 U.S.D.A. grade. The carcass fat was scored numerically from 0 to 6, with 0 the most desirable, being a very hard, white, flaky fat and 6, the least desirable, being a soft and off-colored fat. The chilled carcass was skinned and split in half and the relative amount of fat in the carcass was estimated by a specific gravity determination of the left side. A further measure of fat

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was made through the removal and weighing of the kidney knob and all internal fat anterior to a line from the 4th sacral vertebra to the pubic symphysis (aitchbone).

Flavor scores, press juice quantities and tenderness values were obtained from loin roasts from the left side posterior to the 12th rib and anterior to the ilium. The longissimus dorsi muscle from a comparable position in the right loin was used for moisture, fat, myoglobin and color determinations. The myoglobin content of the longissimus dorsi muscle was determined by the procedure outlined by Ginger *et al.* (1954). The color of the muscle was measured by a Hunter Color and Color Difference Meter. An aperture opening of 1/2 inch and reference color 5R 3/6 was used for the standard.

TABLE 1. AVERAGE DAILY GAIN, LIVE WEIGHT, CARCASS GRADE AND DRESSING PERCENTAGE

Items	Lot 1a Liberal milk	Lot 1b Liberal milk with iron and copper	Lot 2 Limited milk +starter +hay	Lot 3 Milk replacer +starter +hay
Av. daily gain, lb.	2.22	2.39	1.54**	1.31*
Live weight, lb.	178.7	188.6	155.2**	147.8**
Carcass grade[a]	19.6	19.7	14.8**	12.4**
Dressing percent	69.03	69.03	63.34**	63.70**

[a] Numerical scores for average of the grades were: Prime 23, Choice 20.0, Good 17.0, Standard 14.0, Utility 11.0.
* $P<0.05$.
** $P<0.01$.

The quantity of moisture and fat in the loin muscle (longissimus dorsi) was determined by a modified A.O.A.C. procedure (Kelly, 1955). The data were tested for significance by analysis of variance (Snedecor, 1946).

Results and Discussion

Since the data were collected over a 2-year period, the lots were divided into three groups according to the date of birth (Jan. 1–Apr. 30, May 1–Aug. 31 and Sept. 1–Dec. 31) in order to determine if there was an effect due to season. The analysis of the data on this basis showed a greater variation within season than between seasons for the average daily gain, percent yield, carcass grade and myoglobin. Therefore, it was assumed that for the objectives of this experiment there were no seasonal effects.

Information on live grade, stomach weight and capacity, blood hemoglobin and iron and vitamin A content of the liver are given in Part I of this study (Niedermeier *et al.*, 1959). A summary of data pertaining to daily gain, live weight, carcass grade and dressing percentage is shown in table 1.

The calves of lots 1a and 1b produced essentially the same grade carcasses (low to average U.S. Choice). Their average grade was significantly higher at the 1% level than the other two lots. The difference between the average grade of top standard for lot-2 calves and that of low standard for lot-3 calves was also highly significant. This difference of 2/3 grade between these lots should also be of economic importance at a discriminating market. Daily gain and live weight at 6 weeks of age were highly associated with carcass grade, being significantly higher in the milk fed lots. A highly significant correlation between live and carcass grades was found in all lots ($r=.953$, .738, .934, and .886 for Lots 1A, 1B, 2 and 3, respectively.)

The dressing percentage of the milk fed calves (lots 1a and 1b) was the highest (69.03%) and was significantly higher than lots 2 and 3, which dressed approximately 63.5%. The milk fed calves dressed higher and lots 2 and 3 yielded lower than commercially slaughtered calves reported by Schaars and Bray (1950). The average 24-hour, cooler shrinkage for lots 1a, 1b, 2 and 3 were 2.05%, 2.14%, 2.22% and 2.50% of the carcass weight, respectively. These averages suggest a general trend toward greater shrinkages in the lower grades.

Little is known about the factors which determine quality of veal; however, several meat characteristics have been considered as criteria for high quality. Firmness of fat and muscle, as well as color of muscle and amount and character of fat have been used as guides to eating quality of veal. A summary of the chemical and physical measures of moisture, fat and myoglobin is shown in table 2. The effect of the different rations on the color of muscle and amount of fat was apparent in these data.

Loin samples from lots 1a and 1b had the lowest moisture content, 77.5%. This was significantly less ($P<.05$) than lots 2 and 3, which had 78.4% and 78.6% moisture, respectively. These results are in agreement with those reported by Wilson *et al.* (1954). The measurable fat in the longissimus dorsi muscle of veal was very low. Lot 1b contained 0.79% fat and lot 1a 0.61% on a fresh-weight basis. Both were significantly higher than the lots fed either limited whole milk fed or milk replacer fed lots which averaged 0.44% fat; but, these differences probably are not of practical importance.

Carcasses from lots 1a and 1b had the most kidney fat, 1.04% and 1.07%, respectively. These amounts were significantly higher (1% level) than the other two lots. The limited whole milk lot had 0.55% kidney fat which was significantly higher ($P<.01$) than the milk replacer fed lot, 0.25%. Specific gravity values for the carcasses did not vary significantly among lots. This measure of carcass fatness may not be critical enough for measuring the very low quantities of fat in veal carcasses. Likewise, variation in the quantity of bone may be a limiting factor in the use of specific gravity measurements with veal.

The external fat of the carcass was rated from 0 (hard, white and flaky) to 6 (soft, off-color, objectionable). Lot 1a had the most desirable fat, with

an average score of 0.63. Lot 1b ranked second in desirability, with an average of 1.8; a hard, flaky fat characterized this lot, but it generally reflected a reddish cast, thereby reducing its numerical score. In lots 2 (score 2.9) and 3 (score 4.5) the fat was softer and generally had a yellowish or reddish color.

Lot 1b had the largest quantity of myoglobin, 0.54 mg. per gm. of veal. This was significantly higher (1% level) than the other three lots. Lot 1a had the least myoglobin, 0.29 mg. per gm. of veal, and it was significantly ($P<.05$) lower than lots 2 and 3. Since lot 1b had the highest myoglobin

TABLE 2. CHEMICAL AND PHYSICAL MEASURES OF MOISTURE, FAT AND MYOGLOBIN

Items	Lot 1a Liberal milk	Lot 1b Liberal milk +iron +copper	Lot 2 Limited milk +starter +hay	Lot 3 Milk replacer +starter +hay
Moisture,[a] %	77.52	77.53	78.37*	78.57*
Fat,[a] %	0.61	0.79	0.44*	0.44*
Kidney fat weight, gm	598	626	245	111
Kidney fat, percent of carcass weight	1.04	1.07	0.55**	0.25**
Specific gravity	1.070	1.070	1.072	1.077
Myoglobin,[a] mg. per gm. of veal	0.29*[b]	0.54**	0.40	0.35

[a] Longissimus dorsi muscle, fresh basis.
[b] Lower than lots 2 and 3.
* $P<0.05$.
** $P<0.01$.

content, it can be postulated that the increased iron and copper intake provided for a greater production of myoglobin. The lower myoglobin content of lot 1a further suggests that quantity of iron and copper in the ration has an effect on the amount of myoglobin in the muscle.

The lots with larger quantities of myoglobin produced a darker colored veal as observed visually and measured by the Hunter Color and Color Difference Meter. The L value for lot 1b was 27.3, being significantly lower ($P<.05$) than lot 1a with an L value of 29.47. The L values for lots 2 and 3 were 28.28 and 28.34, respectively. The L value indicates the amount of reflection, a lower number indicating more absorption, less reflection and a darker color. A correlation of —0.91 between myoglobin and the L values was highly significant. The higher quantities of myoglobin were associated with darker colored veal, which presently is objectionable according to grading standards.

The hide, liver, gall bladder and thymus gland data are shown in table 3. Hide and liver are important by-products from calves and have a marked influence on their value. Percentage liver, based on live weight, for lot 1a

was 2.18% and for lot 1b, 2.14%. These percentages were significantly higher ($P<0.01$) than lot 2 (1.78%) and lot 3 (1.86%). Schaars and Bray (1950) reported 2.3%–2.4% liver for calves weighing 135–200 lb. Only small variations existed in the hide weights as percentages of the live weight. However, the percentage of hide for lot 2 was significantly lower ($P<.05$) than that for the other 3 lots. No logical explanation can be given for this finding. Schaars and Bray (1950) found that the percentage of hide decreased with increases in live weight.

TABLE 3. HIDE, LIVER, THYMUS GLAND AND GALL BLADDER DATA

Items	Lot 1a Liberal milk	Lot 1b Liberal milk +iron +copper	Lot 2 Limited milk +starter +hay	Lot 3 Milk replacer +starter +hay
Hide weight, lb.	13.3	13.3	10.4	10.8
Hide, live weight basis, %	7.35	7.17	6.83*	7.30
Liver weight, lb.	3.91	3.99	2.74	2.69
Liver, live weight basis, %	2.18	2.14	1.78**	1.86*
Thymus weight, gm.	369	375	263	170
Thymus carcass weight basis, %	0.62	0.72	0.58	0.44[a]
Gall bladder weight, gm.	40	38	41	42[b]

[a] Lot 3 significantly different from lots 1a and 1b at .01 level and from lot 2 at .05 level; lot 2 significantly different from lot 1b at .05 level.
[b] Lot 3 significantly different from lot 1b at .05 level.
* $P<0.05$.
** $P<0.01$.

The weight of the gall bladder and contents was taken to see if fat in the whole milk rations had an effect on bile production. The gall bladder of lot 3 was significantly heavier ($P<.05$) than that of lot 1b. This difference when expressed as percentage of live weight probably is of little practical significance.

The thymus gland (sweetbread) averaged 0.44% of the carcass weight in lot 3. This percentage of thymus was significantly less ($P<.01$) than lot 1a (0.62%) and lot 1b (0.72%) and also ($P<.05$) lot 2 (0.58%). The thymus gland of the limited whole milk fed lot 2 was significantly less at the 5% level than of lot 1b.

The tests of tenderness, flavor and press juice values on the veal samples conducted by the Home Economics Department are reported by Hanning *et al.* (1957).

Summary

Calves receiving whole milk either supplemented with iron and copper or unsupplemented made faster gains and produced higher grading veal than calves fed milk replacer or limited milk with calf starter rations.

The moisture content of the loin samples was lower and the fat content higher in the milk fed lots. The amount of kidney fat was also significantly higher in these lots. The only difference in the veal between the two milk fed lots was a darker color in that of the calves given additional iron and copper.

The lot fed milk replacer, starter and hay produced the lowest grading veal with less kidney fat than the other three lots.

The lots fed whole milk had significantly higher dressing percentage and liver weights.

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EVALUATING THE INFLUENCE OF SEX ON BIRTH WEIGHT AND PREWEANING GAIN IN BEEF CATTLE

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NUMEROUS published reports indicate that the average weights of bulls and heifers differ at all ages, even when raised under similar environmental conditions. Adjustment of weights for these differences is often desired for statistical analysis or for comparisons of means. Two methods of adjustment have usually been used. One method is to add or subtract the average difference in weight between bulls and heifers of comparable ages. A second method is to multiply the weight to be adjusted by the ratio of the average weights of the two sexes. Both methods make the same adjustment in the mean values, but they differ in the adjustments they make for animals at extreme weights. Consequently they differ in their effects on the variance within a sex. Adding or subtracting a constant quantity does not alter the variance of the adjusted group. Using a ratio or multiplicative adjustment does raise or lower the variance within the adjusted group, depending on whether the ratio is larger or smaller than 1.00.

This study evaluates the differences between bulls and heifers in birth weight and gain from birth to weaning and provides evidence on the merit of using either additive or multiplicative adjustment factors.

Data and Methods

The data are birth weights and preweaning gains of beef cattle raised in the experimental breeding herds at the Nebraska Agricultural Experiment Station, Lincoln; the Fort Robinson Beef Cattle Research Station, Crawford, Nebraska; the South Dakota Agricultural Experiment Stations at Reed Ranch, Cottonwood, and Antelope Range; and the Fort Reno Livestock Research Station, El Reno, Oklahoma. The data are from the years 1951–57 at Lincoln and Fort Robinson, 1948–57 at the South Dakota stations, and 1952–57 at the Fort Reno station. The average age of the calves at weaning was about 180 days at Lincoln, 200 days at Fort Robinson, 190 days at the South Dakota stations, and 210 days at Fort Reno.

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The Lincoln data are from cattle of the Hereford, Angus and Shorthorn breeds. At Fort Robinson most (about 80%) of the cattle were Herefords and the remainder were Angus. All cattle from South Dakota were Herefords. About one-fourth of the data from Fort Reno were from Angus and the remainder were from Herefords.

The data were analyzed separately for each sex and station within sire-year subclasses to avoid the effects of genetic and environmental factors that may have differed between groups. The data are from unselected bull and heifer groups. In the South Dakota data some bull calves were castrated before weaning and their records were not included in the comparisons. However, the decision to castrate was based on factors unrelated to gain and, therefore, the omission of these data should not bias the comparisons.

Results and Discussion

The average birth weights and daily gains to weaning at the various stations are shown in table 1 along with the average differences and the ratios of the means of bulls as compared to heifers. The values for birth weight and daily gain, shown in table 1, were computed by weighting the sire-year subclass means by the factor $b\,h/(b+h)$, where b=the number of bull calves and h=the number of heifer calves in the sire-year group. The standard errors were computed from the inverse of these factors and the average mean square within subclasses at each station. This might have been a bit more correct if the weighting factors had utilized the separate mean squares for each sex in the analysis of variance shown in table 2, but inaccuracy from the procedure used here is considered negligible in these data. The standard errors were computed for the Fort Reno data from the average mean squares of all other stations because individual records were not available to the authors for analyzing the variation within subclasses.

The mean squares for the variation within sire-year subclasses for the various sex and station groups are shown in table 2. The variations between subclasses were not reported since they were not pertinent to the study.

The adjustment of weight records for differences in sex, seeks to predict the weight an animal would have if it had been of the opposite sex but every other circumstance had been as it actually was. The change of weights of bulls as compared to heifers can be expressed by the equation

$$\frac{\hat{B}-\bar{B}}{H-\bar{H}}=\frac{s_B}{s_H},$$ where $\hat{B}$ is the adjusted value; $\bar{B}$ is the average weight or gain of bulls; s_B/s_H is the ratio of the standard deviations of weight or gain within each sex; H is the actual and $\bar{H}$ the average heifer weight or gain. From this equation it is easily seen that if the standard deviations of the two sexes are equal, records may be adjusted by adding the difference be-

TABLE 1. AVERAGE BIRTH WEIGHTS AND PREWEANING DAILY GAINS OF BULLS AND HEIFERS

Items	Total no. of animals	No. of sire sub-classes	Birth weight, lb.	Preweaning gain, lb./day
Lincoln				
Bulls	234	48	70.8	1.659
Heifers	222	48	65.3	1.519
Difference (B-H)			5.5±0.92	0.140±0.022
Ratio (B/H)			1.084	1.092
Fort Robinson				
Bulls	523	105	73.6	1.524
Heifers	524	105	68.1	1.437
Difference (B-H)			5.5±0.58	0.087±0.016
Ratio (B/H)			1.081	1.061
Reed Ranch				
Bulls	170	49	73.0	1.674
Heifers	217	49	68.0	1.589
Difference (B-H)			5.0±1.06	0.085±0.033
Ratio (B/H)			1.074	1.053
Cottonwood				
Bulls	126	23	75.4	1.609
Heifers	166	23	70.0	1.578
Difference (B-H)			5.4±1.29	0.031±0.039
Ratio (B/H)			1.077	1.020
Antelope Range				
Bulls	208	44	74.8	1.827
Heifers	224	44	70.1	1.684
Difference (B-H)			4.7±0.98	0.143±0.028
Ratio (B/H)			1.067	1.084
Fort Reno				
Bulls	173	27	71.8	1.856
Heifers	159	27	66.8	1.637
Difference (B-H)			5.0±1.12	0.219±0.032
Ratio (B/H)			1.075	1.133
Average of all stations				
Bulls	1434	296	73.2	1.656
Heifers	1512	296	68.0	1.543
Difference (B-H)			5.2	0.113
Ratio (B/H)			1.076	1.073

tween the mean values of the two sexes. Also, if the coefficients of variation, where $C=s/\bar{x}$, are equal, the ratio of the mean values for the two sexes is the appropriate adjustment.

Birth Weight. The average birth weights were remarkably similar at all the stations as were the average differences between bulls and heifers. The results of this study were not conclusive for choosing between an additive or a multiplicative sex adjustment for birth weight.

The variation among bulls was greater than among heifers in three out of five cases, but F tests for each station and for the pooled data indicated the differences in variation were not statistically significant at the 5% level of

probability. Also, the coefficient of variation among bulls was not significantly different from the coefficient of variation among heifers.

From a practical standpoint the difference between using an additive adjustment factor and a multiplicative factor seems quite small in the case of birth weight. The two types of adjustment would seldom differ more than 1.5 lb. and the error associated with taking birth weights is about ±2 lb. (Koch *et al.*, 1955).

The differences between sexes for birth weight reported in the literature generally fall in the range of 4 to 6 lb. (Botkin and Whatley, 1953; Burris

TABLE 2. VARIATION WITHIN SIRE AND YEAR SUBCLASSES

	Mean square of bulls			Mean square of heifers		
Source of variation	Degrees of freedom	Birth weight	Daily gain to wean	Degrees of freedom	Birth weight	Daily gain to wean
Lincoln	200	77	0.0456	174	67	0.0370
Fort Robinson	422	54	.0474	432	52	.0388
Reed Ranch	124	73	.0683	176	64	.0611
Cottonwood	108	56	.0657	143	63	.0439
Antelope Range	167	65	.0482	183	59	.0503
All stations pooled	1021	63	.0516	1108	59	.0446
Standard deviation		±7.94	±.227		±7.68	±.211

and Blunn, 1952; Dawson, Phillips, and Black, 1947; Gregory, Blunn, and Baker, 1950; Knapp, Lambert, and Black, 1940; Knapp *et al.*, 1942; and Koch and Clark, 1955). The similarity of values reported in the literature with the values found here suggest these results may be applicable over a rather wide range of conditions for the breeds studied.

Daily Gain from Birth to Weaning. Most workers have reported sex differences at weaning as the average difference in weaning weight when standardized for differences in age. In this study the differences between the average daily gains from birth to weaning were used because the ages at weaning varied from 182 days at Lincoln to 210 days at Fort Reno.

Bulls gained significantly more than heifers at all stations although there was considerable variation from one station to another (table 1). The variation among bulls averaged over all stations was significantly greater statistically than the variation among heifers (table2). The ratio of the standard deviations (s_B/s_H) taken from the pooled mean squares of all stations provides an estimate of the regression of daily gain of bulls on heifers and equals 1.075. The ratio of the means averaged over all stations was 1.073. Since the variance among bulls was significantly larger than the variance among heifers, it can be concluded from these data that a multiplicative adjustment factor is more appropriate than an additive factor for gain from birth to weaning. The differences between stations as regards the

actual value of this factor suggest caution until further studies clarify whether the station differences are vagaries of sampling or due to real characteristics of the cattle and environment at different locations.

The average daily gain from birth to weaning varied from one station to another as did the average difference between bulls and heifers. The reasons for the differences between stations are important because they have a bearing on the general applicability of the results. This can be seen by comparing the results at the Lincoln and Fort Robinson stations. The calves at Lincoln had a somewhat higher average daily gain and the difference between sexes was larger at Lincoln than at Fort Robinson. Data on weights

TABLE 3. AVERAGE DAILY GAIN OF CALVES FROM BIRTH TO MID-SUMMER AND MID-SUMMER TO WEANING

Items	Total no. of animals	No. of sire subclasses	Average age at mid-summer	Average daily gain	
				Birth to mid-summer	Mid-summer to weaning
Lincoln					
Bulls	194	42	124	1.706	1.611
Heifers	193	42	124	1.538	1.478
Diff. (B-H)	—	—	—	0.168	0.133
Ratio (B/H)	—	—	—	1.109	1.090
Fort Robinson					
Bulls	445	85	120	1.671	1.246
Heifers	457	85	122	1.545	1.225
Diff. (B-H)	—	—	—	0.126	0.021
Ratio (B/H)	—	—	—	1.082	1.017

taken between birth and weaning were available for most of the years at these stations. The gains computed from these weights were examined to see if they would aid in interpreting this difference. The average daily gains from birth to mid-summer (approximately July 20 at Lincoln, and August 5 at Fort Robinson) and from mid-summer to weaning are shown in table 3. At Lincoln the average daily gain during the latter portion of the grazing season was slightly less than the gain during the first part of the season. The difference between sexes was also slightly less during the latter portion of the season as compared with the difference during the early part of the season. At Fort Robinson the average daily gain dropped markedly during the latter portion of the season (about 77% of the earlier gain) and the difference between sexes dropped from 0.126 for the first part of the season to 0.021 for the later part of the season. These data suggest that the shape of the growth curve as well as the general magnitude of the gains may affect the observed difference between sexes. Data reported by Rollins and Guilbert (1954) from the herd at Davis, California, where growth was at a high level throughout the season, provide an interesting comparison with

the results found here. In their data, calves gained 1.91 lb. per day from birth to 4 months of age and weighed 534 lb. at 240 days, averaging 1.93 lb. per day during the last half of the period. If their birth weight was similar to that reported here (about 73 lb.) the differences between the average daily gain of bulls and heifers were 0.13 for gain during the first 120 days and about 0.39 lb. per day for the last 120 days. Thus, where growing conditions were favorable for rapid growth throughout the season the difference between bulls and heifers increased with age.

The use of a multiplicative type of sex adjustment is indicated by these data. However, because of the large differences between stations, particularly the Fort Reno Station, the general application of the particular factor computed from the present data is not necessarily recommended. This factor might be rather generally valid, but until more evidence on the nature of the differences between stations becomes available it is suggested that each station or herd develop a sex adjustment factor from their own data, provided the results will not be biased by selection. The selection referred to are cases where bull calves were castrated part way through the season because they were not meeting expectations or where some calves were supplied supplemental feed because they appeared to be favorable prospects. In situations where it is not practical to derive the adjustment factor from data in each herd, an adjustment factor developed from a herd or area where environmental conditions are similar seems a reasonable alternative.

Summary

Data on the birth weights and daily gains from birth to weaning of 1434 bulls and 1512 heifers were studied to evaluate the influence of sex on these traits. The mean differences, ratios of the means, and the variation within each sex were evaluated to determine whether an additive or a multiplicative type of adjustment was more nearly appropriate for each trait.

Bull calves averaged 5.2 lb. or 1.076 times heavier than heifers at birth. The data were not conclusive in determining which type of factor was more appropriate. The difference in results from using one type or another is considered too small to be of practical significance.

The daily gain of bull calves from birth to weaning was 0.113 lb. or 1.073 times greater than that of heifers. A multiplicative factor based on the ratio of the mean daily gains was considered more appropriate for the combined data from all of the herds studied. The average daily gain and the average difference between bulls and heifers differed significantly between herds studied. Although a clear cut explanation for the differences between herds was not evident it was postulated that the average magnitude of the gains as well as the shape of the growth curve induced by environmental conditions may have been significant factors.

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A TOPCROSS BREEDING EXPERIMENT WITH OUTBRED AND INBRED HEREFORD SIRES. I. LINE COMPARISONS AND PHENOTYPIC CORRELATIONS [1, 2]

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IN 1950, three lots of Montana Line I Steers from the U. S. Range Livestock Experiment Station, Miles City, Montana, were fed at the Ohio Agricultural Experiment Station. The gains of these steers were compared with those of outbred steers. Results showed that the inbred line steers made daily gains of approximately 0.2 lb. more per head at a cost of $1.62 less per 100 lb. of gain.

These findings led to a breeding project designed to compare the progeny of production selected, inbred sires with calves from outbred bulls which had been selected on beef type. Additional aims of the project were to test existing inbred lines of Hereford cattle for general combining ability and to assist in the development of procedures for improving Ohio beef production generally.

Materials and Methods

This experiment was designed to investigate three lines of breeding. Bulls from two inbred lines were selected on the basis of their gains on a test ration and conformation score while outbred bulls were selected on conformation only. The two performance-tested, inbred lines of Herefords chosen were the Montana Line I and the Nebraska Line I. The outbred bulls were representative of purebred Herford cattle in general and, for convenience in later discussion, these bulls will be referred to as an outbred line.

In the Fall of 1951, 60 Hereford weanling heifer calves were purchased at the Kansas City market and shipped to the Ohio Agricultural Experiment Station. These animals were unregistered and were subsequently used as foundation cows.

Two bulls from each line were purchased yearly and bred to ten experimental cows each. Different bulls were used each year as it was of interest to test line differences rather than individual bull variation. The assignment of the 20 cows to each line was random in the first year. However, in the subsequent two years, cow groups were rotated so that

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those that remained in the herd for the entire experiment were bred to a bull from each of the three lines.

Purchase of the Montana bulls was made from the U. S. Range Livestock Experiment Station, Miles City, Montana, and the Nebraska Line I bulls were obtained directly from the University of Nebraska.

The outbred bulls were procured from Ohio breeders during the first two years, but for the last year were purchased in Texas.

Some replacements for the cow herd were necessary after the first year. Cows which failed to calve and which were the least desirable were culled from the herd. The first replacements were four, 3-year-old cows from the Southeastern Sub-station of the Ohio Agricultural Experiment Station. The second group of replacements, however, numbering thirteen, were registered purebreds bought in Texas and introduced into the experimental herd as yearlings.

It was the practice during this experiment to wean the calves sometime in October. After a period of about 3 weeks the calves were separated by sex and line, giving six groups for dry lot feeding. Calves were weighed at monthly intervals until weaning and subsequently every two weeks throughout the feeding period. From calf records it was possible to estimate 90-day and 182-day weights by linear interpolation. Weight per day of age was calculated for each animal from final weights and ages prior to slaughter. Rather than feeding to a constant weight, the calves were fed, as far as possible, to choice carcass grade. This goal was realized in all but a few cases. Choice grade was reached in June or July when the cattle were slaughtered.

A total of ninety-three fat cattle were sold directly to packing house bidders and did not provide full carcass information. However, 48 animals were slaughtered at the Ohio State University Meats Laboratory and underwent detailed carcass studies. The latter carcasses were chilled, graded and later one-half of each carcass was boned. All meat surfaces were trimmed of excess fatty tissue, the aim of this operation being to leave no more than $\frac{3}{8}$-in. layer of fat on any meat cut. This separated meat was termed edible portion. Fat trim, bone and edible meat were then weighed individually and expressed as a percent of the total weight of the chilled side. Dressing percentages were calculated from the Wooster weights taken on the day of shipping and from the weights of the chilled carcasses.

Two additional carcass variables were investigated, the percent primal cuts and the percent hind. Primal cut proportions were obtained by dividing the sum of the weights of rib, loin end, short loin and round cuts by total carcass weight. The proportion of hind was simply the weight of the rear half of the carcass separated at the 12th rib divided by the total carcass weight. These proportions were multipled by 100 to convert them to percentages.

The number distribution by lines, years and sex of the animals production tested and slaughtered during this experiment is given below:

	Year I		Year II		Year III	
	Steers	Heifers	Steers	Heifers	Steers	Heifers
Montana	12	7	6	5	5	9
Nebraska	6	9	6	13	6	8
Outbred	9	8	10	7	7	8

Simple methods of correlation, regression, analysis of variance and multiple regression were used in analyzing the data. These statistical techniques are fully described by Fisher (1952), Snedecor (1956) and many other authors. In certain sections, nevertheless, some specialized methods were employed and these will be discussed under the appropriate headings.

Results

A Comparison of Line Peformances. An analysis of variance was run on birth weight, weaning weight, gain 90–182 days, weaning score, average daily gain on test and weight per day of age in order to compare line, year and line x year interaction mean squares. The model used is shown in table 1 and mean squares estimated for steers and heifers separately are recorded in table 2. In order to assist the discussion, line and year means with standard errors are given for steers and heifers in tables 3 and 4.

TABLE 1.

ANALYSIS OF VARIANCE MODEL FOR PRODUCTION VARIABLES

SOURCE	S.Sqs	d.f.	M.S.	MEAN SQUARE EXPECTATION	F
LINES	L	a−1	$\frac{L}{a-1} = V_1$	$\sigma_e^2 + K_1\sigma_I^2 + K_2\sigma_L^2$	$\frac{V_1}{V_3}$
YEARS	Y	b−1	$\frac{Y}{b-1} = V_2$	$\sigma_e^2 + K_1\sigma_I^2 + K_3\sigma_Y^2$	$\frac{V_2}{V_3}$
L x Y	I	(a−1)(b−1)	$\frac{I}{(a-1)(b-1)} = V_3$	$\sigma_e^2 + K_1\sigma_I^2$	$\frac{V_3}{V_4}$
ERROR	E	n− ab	$\frac{E}{n-ab} = V_4$	σ_e^2	
TOTAL	T	n− 1			

a= no. of lines = 3
b= no. of years = 3
n= total no. of individuals (64 steers, 74 heifers).

For orthogonal data, K_1= c= no. of animals in lines and years
K_2= bc
K_3= ac

However, as the number of animals in lines and years was variable, the K's are redefined as follows:

$$K_1 = \frac{1}{ab-1}\left(n - \frac{\sum_{ij} K_{ij}^2}{n}\right), \quad K_2 = \frac{1}{b-1}\left(n - \frac{\sum_i (\sum_j K_{ij})^2}{n}\right) \quad \text{and} \quad K_3 = \frac{1}{a-1}\left(n - \frac{\sum_j (\sum_i K_{ij})^2}{n}\right)$$

Where K_{ij} is the number of animals in the j^{th} line in the i^{th} year.

TABLE 2. MEAN SQUARES FOR CERTAIN PRODUCTION CHARACTERISTICS

Characteristics	Steers			Heifers		
	Lines	Years	LxY	Lines	Years	LxY
Birth weight	11.5	212	66	96.5	382.5°	77.8
Weaning weight	4209	7999	2770	324	18454	7584*
Gain 90–182 days	2693*	6874**	361	327.5	9413.5*	1372.25
Weaning score	7.54	.57	3.18	19.39	1.99	9.62**
Test av. daily gain	1555*	.0058	.0118	.130°	.0606	.0256
Wt. per day of age	.0669	.0499	.0401	.0983	.0907	.0371

° ($P<.10$) * ($P<.05$) ** ($P<.01$).

In the case of birth weight, no significant differences between lines were obtained for either steers or heifers, although an inspection of line means indicates that there was a slight tendency for inbred bulls to sire heavier calves. Year differences were, on the whole, larger than line differences and the heavier calves were produced in the second year. However, year mean squares were not significantly larger than the appropriate errors. The difference of 5.3 lb. between steers and heifers was statistically significant.

There were no significant line differences for weaning weight though there seemed to be a small advantage in favor of the inbred lines. Year mean squares were large but insignificant. It was noticed that the average weaning weight increased consistently in both steer and heifer data probably due to the increase in the cow herd age from 2 to 4 years. The large sex difference of 21.7 lb. in favor of the steers was significant. The large line x year interaction for heifers may have been due to sampling error.

Steer gains, 90–182 days, were significantly influenced by lines and highly significantly affected by years. However, the heifer analysis only yielded a significant year affect. Line means show that the Montana steers made greater gains than either the Nebraska or the outbred steers,

TABLE 3. MEANS AND STANDARD ERRORS OF STEER PRODUCTION DATA[a]

Variable	Grand mean	Lines			Years		
		Mont.	Neb.	Out.	1	2	3
Birth weight	73.4	74.1	73.0	72.8	70.5	77.0	73.4
	1.0	1.6	1.8	1.9	1.6	1.8	1.5
Weaning weight	375.1	387.4	361.4	371.4	357.8	369.1	393.2
	7.2	11.3	12.5	13.9	12.1	13.6	11.3
Gain 90–182 days	141.4	152.0	131.8	137.2	139.9	121.0	156.9
	3.8	5.9	6.5	7.2	5.9	6.7	5.6
Weaning score	8.39	7.85	8.53	9.01	8.39	8.19	8.52
	.18	.27	.30	.38	.31	.35	.29
Test av. daily gain	2.18	2.24	2.20	2.08	2.20	2.17	2.18
	.03	.04	.04	.05	.04	.05	.04
Wt. per day of age	2.02	2.07	2.01	1.96	1.97	2.05	2.05
	.02	.04	.04	.04	.04	.04	.04
TDN per cwt. gain	528	537	513	535	517	521	545

[a] The second number in each column is the standard error of the mean and carries a ± sign.

while year means indicate that the third year produced the highest gains during this period of growth. The steer-heifer difference of 9.8 lb. was not significant.

These data did not show statistically significant differences between lines in regard to weaning scores. On the other hand, an inspection of line means indicated a consistent tendency for outbred animals to score higher than progeny from either inbred line. It also seemed as if Nebraska line calves were more desirable at weaning than calves sired by Montana bulls.

TABLE 4. MEANS AND STANDARD ERRORS OF HEIFER PRODUCTION DATA [a]

Variable	Grand mean	Lines			Years		
		Mont.	Neb.	Out	1	2	3
Birth weight	68.1	67.9	70.1	66.2	64.0	71.7	67.1
	.83	1.4	1.4	1.4	1.4	1.2	1.3
Weaning weight	353.4	354.5	356.4	349.4	322.7	354.0	381.0
	6.3	11.2	11.0	11.0	11.0	9.2	10.5
Gain 90–182 days	131.6	132.7	127.6	134.6	121.0	118.9	155.1
	3.6	6.3	6.2	6.2	5.8	4.8	5.5
Weaning score	7.83	6.80	8.22	8.44	7.50	7.85	8.10
	.19	.30	.29	.29	.35	.29	.34
Test av. daily gain	1.99	2.30	2.04	1.91	2.05	1.96	1.96
	.02	.04	.04	.04	.04	.03	.04
Wt. per day of age	1.88	1.92	1.92	1.81	1.80	1.92	1.90
	.02	.03	.03	.03	.04	.03	.04
TDN per cwt. gain	544	521	538	574	518	552	561

[a] The second number in each column is the standard error of the mean and carries a ± sign.

There was good evidence from the tables of mean squares that definite line differences in regard to daily gain existed. The inbred lines gained consistently higher in both sexes. However, there was no indication of difference between the Montana and the Nebraska lines, while the overall effect of years was small. Once again there was a sex advantage for steers, and the difference of 0.19 lb. was highly significant.

Weight per day of age also seemed to be influenced by lines, although the line mean squares were not significant. Inbred lines appeared to exceed the outbred line. Year effects were quite marked and high weights were obtained in the second and third years. This higher rate of gain is most likely attributable to the increasing age of the dams. Steers, generally, had a significantly higher rate of gain than heifers.

The pounds of TDN. consumed per cwt. gain were calculated to give an indication of feed efficiency. In every case, excepting the last year, inbred steers and heifers required less TDN. per cwt. of gain than the outbreds. This advantage was partially nullified by the large amount of ground ear corn eaten by the Montana steers in the 1955–1956 feeding period. Average TDN. requirements are listed for steers and heifers in tables 3 and 4, respectively.

In order to separate the effects of lines, years and sex on TDN. require-

ments per 100 lb. of gain, a three-way analysis of variance was run; the results are shown in table 5. These results indicate no significant differences among lines, years or sex, although the mean squares for lines and years were considerably larger than their respective errors. Nevertheless, one is tempted to interpret this analysis liberally as the general consistency with which the inbred lines outperformed the outbred line in respect to TDN. requirements is highly suggestive of line differences. In addition, Montana and Nebraska cattle made higher daily gains than outbred animals and, hence, increased efficiency would be expected for the former two lines as feed efficiency and daily gains are positively correlated.

TABLE 5. ANALYSIS OF VARIANCE OF T.D.N. REQUIREMENTS[a]

Source	S.sqs	d.f.	M.S.	F
Lines	3321	2	1660.5	1.91
Years	3718	2	1859	2.13
Sex	1120	1	1120	.66
LxS	3184	2	1592	—
YxS	676	2	338	—
LxY	3486	4	871.5	—
SxLxY	979	4	244.75	—
Total	16484	17	—	—

[a] In this analysis, lines and years are considered random variables and sex a fixed variable.

Carcass Data. It has been mentioned previously that 48 cattle from this breeding experiment were slaughtered at the Ohio State University Meats Laboratory. In the first two years, two animals of each sex from each line underwent detailed carcass study. In the third year, this number was increased to four. Thus, at the completion of the breeding project carcass data were available for eight steers and eight heifers from each line.

An analysis of variance was run to test the significance of differences between sexes, lines and years. The model which was used is outlined in table 6, and the results of the analyses are recorded in table 7. The means and standard errors of carcass variables are recorded by lines, years and sex in table 8.

The appropriate error term for testing sex differences must be composited from other terms since lines and years are considered random variables and sex is considered a fixed variable. Methods described by Shultz (1954) have been followed here. The arrangement of the F ratio in the manner shown requires the calculation of degrees of freedom for both numerator and denominator. Formulae necessary for these computations are given at the bottom of the table. The test as applied here was rather conservative as, whenever fractional degrees of freedom were estimated, the nearest, lowest integer was taken for reference in the F table.

From this analysis it is apparent that the mean squares for sex were

TABLE 6.

ANALYSIS OF VARIANCE MODEL FOR CARCASS VARIABLES

SOURCE	S.Sqs	d.f.	M.S.	MEAN SQUARE EXPECTATION	F *
SEX	S	a−1	$\frac{S}{a-1}=V_1$	$\sigma_\varepsilon^2+K_6\sigma_{SL}^2+K_7\sigma_{SY}^2+K_8\sigma_{SLY}^2+K_9\sum\frac{S_i^2}{S}$	$\frac{V_1+V_7}{V_5+V_6}$
LINES	L	b−1	$\frac{L}{b-1}=V_2$	$\sigma_\varepsilon^2+K_5\sigma_{SL}^2+K_6\sigma_L^2$	$\frac{V_2}{V_6}$
YEARS	Y	c−1	$\frac{Y}{c-1}=V_3$	$\sigma_\varepsilon^2+K_6\sigma_{SY}^2+K_7\sigma_Y^2$	$\frac{V_3}{V_6}$
S x L	SL	(a−1)(b−1)	$\frac{SL}{(a-1)(b-1)}=V_4$	$\sigma_\varepsilon^2+K_5\sigma_{SLY}^2+K_8\sigma_{SL}^2$	$\frac{V_4}{V_7}$
S x Y	SY	(a−1)(c−1)	$\frac{SY}{(a-1)(c-1)}=V_5$	$\sigma_\varepsilon^2+K_6\sigma_{SLY}^2+K_8\sigma_{SY}^2$	$\frac{V_5}{V_7}$
Y x L	YL	(b−1)(c−1)	$\frac{YL}{(b-1)(c-1)}=V_6$	$\sigma_\varepsilon^2+K_9\sigma_{SLY}^2$	$\frac{V_6}{V_7}$
S x L x Y	SLY	(a−1)(b−1)(c−1)	$\frac{SLY}{(a-1)(b-1)(c-1)}=V_7$	$\sigma_\varepsilon^2+K_9\sigma_{SLY}^2$	$\frac{V_7}{V_8}$
ERROR	E	n−abc	$\frac{E}{n-abc}=V_8$	σ_ε^2	
TOTAL	T	n−1			

a = no. of sexes = 2

b = no. of lines = 3

c = no. of years = 3

n = total no. of animals = 48

$K_1=\frac{1}{abc-1}\left(n-\frac{\sum_{ijr}K_{ijr}^2}{n}\right)=2\cdot65$

$K_2=\frac{1}{ac-1}\left(n-\frac{\sum_{ir}K_{ir}^2}{n}\right)=7\cdot8$

$K_3=\frac{1}{ab-1}\left(n-\frac{\sum_{ij}K_{ij}^2}{n}\right)=8$

$K_4=\frac{1}{a-1}\left(n-\frac{\sum_{i}K_{i}^2}{n}\right)=24$

$K_5=\frac{1}{bc-1}\left(n-\frac{\sum_{jr}K_{jr}^2}{n}\right)=5\cdot25$

$K_6=\frac{1}{b-1}\left(n-\frac{\sum_{j}K_{j}^2}{n}\right)=16$

$K_7=\frac{1}{c-1}\left(n-\frac{\sum_{r}K_{r}^2}{n}\right)=15$

i = lines j = years r = sex

* d.f. $(V_1+V_7)=\left[\frac{(V_1+V_7)^2}{\frac{V_1^2}{a-1}+\frac{V_7^2}{(a-1)(b-1)(c-1)}}\right]$

d.f. $(V_5+V_6)=\left[\frac{(V_5+V_6)^2}{\frac{V_5^2}{(a-1)(c-1)}+\frac{V_6^2}{(a-1)(b-1)}}\right]$

generally larger than those from any other source of variability. However, the test of significance yielded only one statistically significant mean square, that for percentage fat, while two others, percentage primal cuts and edible portion, approached significance. Actual sex differences are given below together with their standard errors.

Item	Dressing percentage	Percent edible portion	Percent bone	Percent fat	Percent primal cuts	Percent hind
Steer av. minus heifer average	0.53	2.50	1.53	−3.88	0.71	−1.13
	±.40	±.52	±.28	±.64	±.27	±.23

An inspection of the above figures can leave little doubt that the F test of sex mean squares was indeed conservative. The only difference which did not appear to be real was that of dressing percentage. It seems

TABLE 7. MEAN SQUARES FOR CARCASS DATA

Variable	Sex	Lines	Years	SxL	SxY	LxY	SxLxY
Dressing percentage	3.46	1.79	2.43	.76	3.69	1.52	5.53**
Percentage edible portion	75.26°	2.37	26.88**	0	7.09	1.43	1.87
Percentage bone	21.2	.67	.24	1.13	4.45*	1.88*	.63
Percentage fat	180.57*	6.27°	33.66**	1.50	8.52*	1.38	.24
Percentage primal cuts	6.02°	1.01	6.25°	.54	.18	1.20	.72
Percentage hind quarter	15.41	.68	.12	.26	2.78**	.63	.09

° ($P<.10$) * ($P<.05$) ** ($P<.01$).

that heifers tend to be fatter than steers at choice carcass grade. Consequently, steers have higher edible portion, bone and primal cuts percentages. On the other hand, the difference between heifer and steer carcasses in respect to the percentage of the total carcass weight in the rear half is well explained by anatomical variations expected between the two sexes.

No significant line differences were found in these data, although the mean square for percentage fat was near significance. These conclusions are supported by the means and standard errors in table 8. Some large

TABLE 8. MEANS AND STANDARD ERRORS FOR CARCASS DATA [a]

Variable	Sex		Lines			Years		
	Steers	Heifers	Mont.	Neb.	Out.	I	II	III
Dressing percentage	60.86	60.33	60.90	60.64	60.24	60.94	60.08	60.68
	.28	.28	.34	.34	.34	.39	.39	.28
Percentage edible portion	68.73	66.23	67.91	67.38	67.16	68.03	68.95	66.48
	.37	.37	.56	.56	.56	.56	.53	.37
Percentage bone	15.50	14.17	15.06	14.68	14.76	15.00	14.82	14.75
	.20	.20	.29	.29	.29	.34	.34	.24
Percentage fat trim	15.74	19.62	16.97	17.91	18.16	16.88	16.16	18.83
	.45	.45	.73	.73	.73	.79	.79	.56
Percentage primal cuts	46.17	45.46	45.77	45.59	46.09	45.88	46.63	45.38
	.19	.19	.25	.25	.25	.25	.25	.18
Percentage hind quarter	48.44	49.57	48.97	48.83	49.23	48.83	49.38	48.90
	.16	.16	.24	.24	.24	.27	.27	.19

[a] The second number in each column is the standard error of the mean and carries a $\pm$ sign.

year differences, however, were evident, in particular edible portion, fat and, to a lesser extent, primal cuts percentages. These large mean squares were primarily due to the increase in carcass fat trim in the last year of the experiment with a consequent lowering of edible portion and primal cuts percentages. The 1955–1956 crop of calves were slightly less efficient than those of the previous years, and the extra consumption of TDN. per lb. of gain may be reflected in the extra fat trim.

The sex x year interaction mean squares were generally larger than any of the other interactions. These large mean squares are not easily explained. One hypothesis could be that steers and heifers had reached different stages of the growth curve at choice carcass grade and any change in the average feeding period or in feed management generally could thus affect one sex more than another. Whatever the explanation, it is clear that, in future work, experiments should be designed so that these interactions can be removed by analysis as was possible in this case.

A highly significant second order interaction was obtained for dressing percentage. One is inclined to regard this as pure sampling error, although there was a tendency during the shipping and slaughtering of the cattle for animals of different sexes, lines and years to be handled as

separate groups. Hence, this relatively large mean square could result from differential environment the day prior to slaughter.

Phenotypic Correlations. From the calf records, 15 variables were selected for study. Zero order correlations were run on an intra-sex basis and production data were available for 67 steers and 74 heifers. However, as only 24 steers and 24 heifers were slaughtered at the Ohio State University Meats Laboratory, all correlations involving the six carcass traits were calculated from these observations.

These correlations and their significance have been discussed fully elsewhere (Tallis, 1957). However, the most important findings appear to be:

1. Birth weight, 90-day weight and 182-day weaning weight were all highly and positively correlated with weight per day of age. This indicates the possibility of selection at an early age for overall growth.

2. Birth weight had a higher correlation with test gains than any other pre-weaning variable.

3. Pre-weaning gains made from 90 to 182 days showed significant negative correlations with edible portion and primal cuts percentages. An explanation for this is that heavy calves at weaning may have reached a later part of the growth curve. Hence post-weaning gains for these calves may consist of a higher proportion of fatty tissue than gains made from lighter calves. Fatter carcasses would inevitably result in lower edible portion and primal cuts.

4. Gains made during the first 98 days of test appeared to be positively correlated with dressing percentage.

Summary and Conclusions

The results of a three-year, top-cross breeding experiment with three lines of Hereford cattle have been reported. Montana Line I and Nebraska Line I bulls were selected on type and feed lot performances and subsequently bred to randomly selected, outbred cows. The performance of the progeny of these inbred line bulls were compared with those of outbred bulls which had been selected on beef type. A total of 67 steers and 74 heifers were studied.

Analysis revealed surprisingly few line differences. Nevertheless, evidence is strong enough to suggest real advantages in favor of the two inbred lines in respect to gain 90–182 days, average daily gain on test and weight per day of age. These data tend to show that the Montana Line I and Nebraska Line I sired calves tended to be more efficient in their conversion of TDN. to meat. However, no useful line effects were observed in the carcass data. A brief discussion of phenotypic correlations among 15 variables (9 production variables and 6 carcass traits) is also included.

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EFFECT OF PROTEIN LEVEL AND QUALITY IN SWINE RATIONS UPON GROWTH AND CARCASS DEVELOPMENT [1]

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CONSUMER demand for leaner pork cuts and less fat has made it imperative to develop and test feeding and management practices which might result in a more desirable muscle to fat ratio in swine.

Osborne and Mendel (1915, 1916) have stressed that lack of certain dietary factors, such as essential amino acids, may hinder the synthesis of muscle protein. Mitchell (1939) concluded that equal body weight gains in hogs produced by rations varying in protein level might not necessarily result in equal amounts of tissue protein. One might speculate that in the young growing pig growth, feed efficiency and carcass value may be enhanced if the dietary amino acids are in a favorable ratio to each other and to other nutrients in the ration.

This study was undertaken in order to determine the effect of ration protein level and protein quality upon growth, feed efficiency and certain carcass characteristics during various stages of growth.

Materials and Methods

Sixty-three pigs weighing from 24 to 67 lb. were allotted on the basis of initial weight and breeding into nine groups of seven pigs each. Three groups, or 21 pigs, were placed on each of three rations (table 1). Lot 1 received a 16% protein ration which was calculated to contain a satisfactory quantity and balance of the essential amino acids based on recommendations published by the National Research Council (1953). Lot 2 received a 16% protein ration with a poor balance of the essential amino acids. Lot 3 received a ration that was similar to that of Lot 1, but contained only 12% protein. All pigs were self-fed in drylot.

Seven hogs from each feeding group were designated for slaughter at each of the following weights: 85, 145 and 205 lb. The individuals within each group were removed for slaughter as they reached the predetermined weight for their group. Pigs were kept off feed for 24 hours prior to slaughter. At the time of slaughter the following weights were obtained:

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Live weight, dressed weight (packer style), weight of viscera (full), liver, kidneys and leaf fat.

After a 24- to 48-hour chill at 34 to 36° F., physical measurements were taken, standard cuts were made and samples were removed for analyses. Backfat thickness was determined on the split carcass at the 1st rib, last rib and last lumbar vertebra. Specific gravity was determined for the chilled carcass. The right side was cut into standard wholesale cuts as recommended by the Pork Carcass Committee of the Reciprocal Meats Conference (National Live Stock and Meat Board, 1952). Longissimus dorsi muscle area was determined at the 10th rib and a sample of this

TABLE 1. COMPOSITION OF RATIONS [a]

Constituents	Lot 1 16% protein, good amino acid balance	Lot 2 16% protein, poor amino acid balance	Lot 3 12% protein, good amino acid balance
Feeds, lb.			
Ground yellow corn	71	72	83
Soybean oil meal	15	—	3
Alfalfa meal	5	5	5
Dried skim milk	5	—	5
Brewers' yeast	3	—	3
Corn gluten meal	—	10	—
Peanut meal	—	12	—
Trace mineral salt	0.5	0.5	0.5
Ground limestone	0.5	0.5	0.5
Amino acids,[b] %			
Lysine	0.78	0.41	0.53
Tryptophan	0.17	0.13	0.13
Methionine	0.33	0.32	0.27
Cystine	0.24	0.24	0.16

[a] Choline, riboflavin and pantothenic acid were added as necessary to meet National Research Council recommended allowances. Zinc sulphate heptahydrate added to furnish 100 ppm. zinc.
[b] Calculated from values reported by National Research Council (1953).

muscle was taken for analysis between the 10th and 14th thoracic vertebrae. The left side of the carcass, excluding the bone and skin, was ground and mixed three times. A 10 lb. sample from this side was placed in a silent cutter and homogenized before a final sample of approximately 2 lb. was removed, quick frozen and stored. Moisture was determined by drying in an oven at 95–100° C. for 24 hours. Fat was determined by extracting the moisture-free sample with diethyl ether for 12 to 16 hours. Protein nitrogen was determined by the Kjeldahl method as outlined in A.O.A.C. (1955).

Analysis of variance was used to determine if statistical differences existed in growth and carcass data. In such cases, Duncan's multiple range test was applied to locate interlot differences (Duncan, 1955).

Results and Discussion

Growth and feed utilization data are presented in table 2. Equal rates of gain were noted in the swine which received good quality protein (Lots 1 and 3). Growth rate was reduced in pigs receiving the poor quality protein ration (Lot 2). Daily feed consumption was also reduced in Lot 2 and more feed was required per unit of gain. Mertz *et al.* (1952) have shown that when the amino acid balance in the ration is improved, the amount of protein required for optimum growth may be substantially reduced. It appears that the addition of small quantities of high quality protein sources such as brewers' yeast or dried skimmilk to swine rations

TABLE 2. GROWTH AND FEED UTILIZATION DATA

Items	Lot 1 16% protein, good amino acid balance	Lot 2 16% protein, poor amino acid balance	Lot 3 12% protein, good amino acid balance
No. pigs on experiment	21	21	21
Days on expt., av.	72.5	98**	73
Av. initial wt., lb.	42.7	42.7	42.8
Av. final wt., lb.	146.0	145.0	146.1
Av. daily gain, lb.	1.43	1.05**	1.42
Total feed consumed, lb.	7241	8225	7334
Av. daily feed, lb.	4.76	4.01	4.80
Feed/cwt. gain, lb.	334.0	382.9	338.0

** $P<0.01$.

may allow for reduction in protein level if one compares the gains of Lot 3 with that of Lot. However, these two feedstuffs are also excellent sources of B-vitamins, and certain of these vitamins may be involved in this effect. All B-vitamins, with the exception of vitamin B_{12} were calculated and were found to meet National Research Council allowances for swine, but rations of Lots 1 and 3 contained a higher natural content than did the ration of Lot 2.

Since growth is limited by any factor which reduces protein synthesis, it appears that the low content of the essential amino acid lysine in the protein of the Lot 2 ration may have been such a limiting factor. The reduced feed consumption of Lot 2 and also the lowered feed efficiency admittedly may have been partly due to the unpalatability of this ration. However, the greater feed efficiency in Lots 1 and 3 was expected, since protein of those rations contained greater amounts of lysine.

Lots differed significantly with regard to dressing percentage. Dressing percentage was lowest in Lot 2 (16% poor quality protein) and highest in Lot 3 (12% good quality protein table 3). Conversely, unemptied viscera weight in Lot 2 was significantly greater; however, pigs in Lot 2 did not consume as much feed per day.

TABLE 3. AVERAGE SLAUGHTER AND CARCASS DATA [a]

Lot and treatment	Slaughter weight, lb.	Dressing % (cold)	Total % of live weight	Leaf fat wt., lb.	Liver wt., lb.	Kidney wt., gm.	Av. fat back, inches [b]	Longissimus dorsi area, sq. in. 10th rib	Carcass specific gravity		Lean cuts, %		Fat cuts, %
									M	F	M	F	
Lot 1													
16% protein,	85	60.4	15.48	0.9	2.2	172	0.81	1.96	1.046	1.045	54.66	56.44	28.16
good amino	145	67.1	12.21	2.6	2.7	212	1.28	2.81	1.032	1.037	50.98	53.76	32.57
acid balance	205	70.7	10.18	6.3	2.9	250	1.68	3.72	1.028	1.034	49.22	50.80	35.35
Lot 2													
16% protein,	85	60.6	16.33	1.4	1.8	130	0.85	1.52	1.034	1.035	53.26	53.76	29.73
poor amino	145	65.2	12.99	3.2	2.7	198	1.26	2.28	1.026	1.030	49.52	51.87	33.69
acid balance	205	69.8	10.50	6.1	3.0	251	1.72	3.25	1.022	1.026	46.73	49.59	37.90
Lot 3													
12% protein,	85	62.0	15.00	1.1	2.0	146	0.96	1.89	1.036	1.041	51.22	53.57	30.56
good amino	145	66.7	12.28	2.9	2.7	193	1.39	2.65	1.023	1.029	48.81	50.79	34.86
acid balance	205	72.5	9.53	5.7	2.9	252	1.73	3.78	1.026	1.025	48.95	48.16	36.41
Treatment		**	*	N.S.	N.S.	N.S.	*	**	**	**	N.S.	**	**
Differences [c]		1x2, 3 2x3	2x3				1x3	2x1, 3	1x2, 3	1x2, 3		1x2, 3	1x2, 3
Stage differences		**	**	**	**	**	**	**	**	**	**	**	**
Stage x treatment interaction		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

[a] Where sexes differed, barrows and gilts were analyzed separately; otherwise, data were combined. M indicates barrows, F indicates gilts.
[b] Average of measurements at 1st rib, last rib and last lumbar vertebra.
[c] N.S.=nonsignificant differences; *=$P<0.05$; **=$P<0.01$. Numbers indicate where differences existed, i.e., 1x2, 3 means that Lot 1 differs significantly from Lots 2 and 3.

TABLE 4. AVERAGE RESULTS OF TISSUE ANALYSES [a]

Lot and treatment	Slaughter weight, lb.	Carcass composite						Longissimus dorsi muscle			Liver
		Moisture, %		Fat, (fresh) %		Protein, %		Fat, (fresh) %		Protein, % (combined)	Protein, % (combined)
		M	F	M	F	M	F	M	F		
Lot 1											
16% protein,	85	54.20	54.38	31.52	31.94	12.23	12.51	2.10	1.37	20.91	20.71
good amino	145	45.58	50.06	42.48	36.29	11.37	12.99	4.18	1.36	21.94	21.09
acid balance	205	41.56	45.52	46.68	42.08	11.10	12.28	3.73	2.52	22.00	21.25
Lot 2											
16% protein,	85	48.90	47.91	39.38	40.90	11.54	11.01	3.80	2.91	19.21	20.62
poor amino	145	42.56	45.24	46.40	43.32	9.98	10.62	6.68	5.26	19.01	21.10
acid balance	205	39.37	44.91	50.06	43.06	9.97	10.92	6.49	2.08	20.16	20.72
Lot 3											
12% protein,	85	48.14	49.52	40.29	37.90	10.97	12.05	2.93	2.14	20.28	20.37
good amino	145	43.03	44.07	46.39	44.64	10.16	10.81	4.16	3.96	19.73	21.06
acid balance	205	41.67	39.97	46.88	49.02	10.14	10.11	4.44	4.86	21.40	21.40
Treatment		**	**	**	**	**	**	*	**	**	N.S.
Differences [b]		1x2, 3	1x2, 3	1x2, 3	1x2, 3	1x2, 3	1x2, 3	1x2	1x2, 3	1x2, 3 2x3	
Stage difference		**	**	**	**	**	**	**	*	**	N.S.
Stage x treatment interaction		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	*	N.S.	N.S.

[a] Where sexes differed, barrows and gilts were analyzed separately; otherwise, data were combined. M indicates barrows, F indicates gilts.

[b] N.S.=nonsignificant differences; *=$P<0.05$, **=$P<0.01$. Numbers indicate where differences existed, i.e., 1x2, 3 means that Lot 1 differs significantly from Lots 2 and 3.

No significant over-all difference was noted in liver-, kidney- or leaf-fat weight, but an apparent difference existed at the 85-lb. stage of growth. The higher levels of dietary amino acids may have resulted in a proportionately larger sized liver and kidney. Woodman *et al.* (1936) and Carroll *et al.* (1939) found greater liver and kidney weights to be associated with a lighter protein level in the ration.

Differences were noted between barrows and gilts in carcass specific gravity, percentage of lean cuts, carcass composite moisture, fat and protein, and fat content of the longissimus dorsi (tables 3 and 4). Gilt carcasses were more muscular and contained less fat in all cases. Self *et al.* (1957) had reported that gilt carcasses were significantly longer and had greater cross sectional area of the longissimus dorsi muscle than barrow carcasses of equal weight. The superiority in terms of muscling of carcasses from gilts has also been reported by Lacy (1932) and Parks (1930). When a significant difference was shown between sexes with regard to a given characteristic, data from the barrows and the gilts were analyzed separately since the sexes were not divided equally among treatments. The composition of gilt carcasses seemed to be affected more by treatment than barrow carcasses; however, this difference was not statistically significant except in the case of lean cut yield. Since gilt carcasses were more muscular, these data suggest that during growth, carcass composition of gilts may be more sensitive to changes in quality and quantity of ration protein.

Whereas, gain in body weight may not be affected by a certain limitation in level or quality of protein, the ultimate in measurement of the desirability of a given swine ration should not be measured by total weight gain, but by the effect upon carcass composition. Theoretically, a higher dietary protein level or a superior quality protein should result in greater muscle development and less fat deposition. This was verified in this experiment by increased longissimus dorsi cross sectional area, greater carcass specific gravity, higher lean cut yield (in gilt carcasses) and a reduced backfat thickness and fat cut yield in the pigs receiving the high level of good quality protein. This was true for each of the three stages of growth studied. Furthermore, carcass composite samples from these pigs were found to contain less fat and more moisture and protein. Results of Carroll *et al.* (1935–36) and Ashton *et al.* (1955) with swine, and Hamilton (1939) with rats have shown higher content of the diet to be associated with increased carcass moisture and protein, and with reduced fat content.

No significant interactions between treatment and slaughter weight were found for any of the characteristics reported in this study, with the one exception being a significant interaction for fat content of the longissimus dorsi in gilts. This interaction may possibly be attributed to sampling or experimental error.

All treatment groups varied significantly from each other with regard

to the protein content of the longissimus dorsi. The highest protein content of this muscle was found in pigs receiving the 16% good quality protein ration (Lot 1) and lowest in those receiving the 16% poor quality ration (Lot 3). By contrast, the fat content of the longissimus dorsi was significantly lower in Lot 1. This suggested that marbling or intramuscular fat was less developed in carcasses from animals receiving the high level, high quality protein ration. No significant interlot differences in liver protein level were noted.

Treatment differences in carcass muscling seemed to be larger at earlier stages of growth. Both Carroll *et al.* (1939) and Bell and Loosli (1951) reported that as the animal matured the relative amount of protein needed for growth decreased. At a constant nitrogen intake a decreasing proportion was used for tissue growth. The fact that treatment differences in favor of Lot 1 are greater at lighter body weights leads to speculation. Perhaps the rations of Lot 2 (16% poor quality protein) and Lot 3 (12% good quality protein) were more limiting in regard to essential amino acid content in the earlier stages of growth and thus retarded muscle development. However, at heavier body weights, these same rations may have been more than adequate. If this is true, one might theorize further that muscle development which has been so retarded can be stimulated later in the growth period with a ration adequate in the essential amino acids.

Summary

Rations containing 16% and 12% total protein were found to support good growth of swine from weaning to 200 lb., when these rations contained small amounts of a high quality protein source such as brewers' yeast and dried skimmilk.

Dressing percentage was lowest in the slowest gaining group, which received the 16% poor quality protein ration. The weights of liver, leaf fat and kidneys were not affected by treatment. However, there was a tendency toward heavier liver and kidneys and less leaf fat at early growth stages in pigs fed the superior ration.

Gilt carcasses contained more muscle and less fat than carcasses from barrows. Carcasses from pigs fed a 16% good quality protein ration were more muscular as shown by a greater cross sectional area of the longissimus dorsi muscle (except at 205 lb.), increased carcass specific gravity, higher levels of carcass protein and decreased fat back thickness. The intramuscular fat of the longissimus dorsi was lowest and the percentage moisture in the carcass was highest in the 16% good quality protein group. It appeared that carcass muscle development was more severely hindered in early growth than in later growth by low protein level and/or quality.

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RELATIONSHIPS BETWEEN CHEMICAL COMPOSITION AND SOME NUTRITIVE QUALITIES OF LESPEDEZA SERICEA HAYS

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SOME investigators question the value of proximate analyses as an estimate of the nutritive value of forages. Nevertheless, other investigators have shown a close correlation between chemical composition of feeds and certain of their nutritive qualities (Forbes and Garrigus, 1950; Richards and Reid, 1952; Lancaster, 1943; Phillips and Loughlin 1949; Mitchell, 1942).

Certainly a consistent relationship between chemical composition of forages and animal performance would be invaluable to the plant breeder in developing improved varieties of crops. *Sericea lespedeza* is adapted to soils and climates of most of the Southern part of the United States. Generally, however, suboptimum performance is obtained when animals are fed this legume. Consequently, a breeding program was begun at this Experiment Station several years ago to develop a more nutritious variety of sericea. The study reported here was made to determine the usefulness of chemical composition as a tool in selection of plants.

Experimental

Forages. The hays used in this study were first and second cuttings of sericea grown at five locations in Alabama. In order to reduce the effects of differences in texture on palatability, all hays were ground in a hammer mill to pass a ½-in. mesh screen. The hays were leafy and green in color and were rated (unofficially) U.S. No. 2. Aliquots of the hays as fed were taken on 3 days and composited for analyses.

Animals, Feeding and Management. Jersey and Holstein steers weighing between 470 and 595 lb. were the experimental subjects. Each hay was fed to three steers during an 8-day test period. Twice daily the steers were individually fed more hay than they would eat. Quantities of the hays fed and refused were measured and recorded. Water was offered to the steers at each feeding period. Block salt was available at all times. The steers were housed in individual tie stalls that were bedded with wood shavings.

Digestion Trial and Chemical Analyses. Prior to feeding on the ninth day, between 5 and 6 a.m., fecal collections were made by the grab method. Diurnal variation in lignin excretion has been demonstrated by Kane *et al.*, 1952. Nevertheless, according to their data, the percentage of lignin in feces from a single collection made between 4 and 6 a.m. and that from a

nine-day total collection differed by only about 2%. For this reason, only one collection was made from each steer for each forage studied. Within 2 hours after collection, the feces were placed in an oven to dry at 60°–70° C. Subsequently, the digestibility of the hays was measured by the lignin ratio method of Ellis *et al.*, 1946.

Moisture, protein, ether extract, crude fiber, nitrogen-free extract, and ash were determined by Official Methods of Analysis (1950) and cellulose was measured by the method of Crampton and Maynard (1938). the quantity of tannin in the hays was measured by the method of Valaer (1941) with modifications that are in use at this Station (Hawkins, 1955).

Results and Discussion

Data on composition of the 10 sericea hays are given in table 1. The range of crude protein content of the hays was from 10.5 to 16.6% and that of lignin was 16.8 to 23.7%. Also, the ranges of other constituents were large. Values previously reported on the average composition of sericea hays (Hawkins, 1955; McCullough *et al.*, 1953) fall within the ranges reported for these 10 hays.

Data on consumption, digestibility of dry matter, and apparent digestibility of protein of the hays are presented in table 2. Average daily intake of the hays per 100 lb. of bodyweight was 2.96 lb. and the range was 2.30 to 3.53 lb. Mean intakes of most of these hays were unusually large in comparison with intakes of other sericea hays (Hawkins and Autrey, 1954; Hawkins, 1955, 1958; McCullough *et al.*, 1953). Some factors that probably contributed to the relatively large intakes were: (a) no other feed was available during the experiment, (b) sericea hay was the only feed the steers received during the 3 months before going on test, and (c) the steers were thrifty but not fat.

Differences were found in the digestibility of the dry matter and the apparent digestibility of the protein of the sericea hays. Thus, these hays afford a logical basis for evaluating the relationships between chemical composition and digestibility.

TABLE 1. COMPOSITION OF SERICEA HAYS, DRY MATTER BASIS

Hay	Protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Lignin	Cellulose	Tannin	O.C.[a]
1	15.2	3.8	27.1	49.6	4.3	22.0	34.4	3.7	42.3
2	10.5	2.2	34.6	48.4	4.3	18.9	39.7	4.0	43.3
3	11.8	3.4	30.0	46.6	8.2	21.6	31.5	3.6	45.1
4	12.0	1.6	30.0	50.5	5.9	21.6	37.9	3.1	42.6
5	16.5	2.7	34.4	41.5	4.9	19.7	38.7	3.9	37.2
6	13.7	1.9	32.1	47.8	4.5	21.2	35.6	4.4	44.3
7	12.2	3.1	37.4	40.8	6.6	16.8	45.4	1.7	32.7
8	16.6	2.5	28.5	47.7	4.7	23.7	37.7	3.5	38.5
9	13.5	3.0	36.8	41.2	5.5	16.8	39.3	2.8	38.7
10	14.3	2.2	34.1	45.0	5.4	23.7	37.8	4.1	41.3
Means	13.6	2.6	32.5	45.9	5.3	20.6	37.8	3.5	40.6

[a] O.C. (Other Carbohydrates) = 100 − (C.P. + E.E. + Cellulose + Ash).

TABLE 2. DAILY INTAKE OF HAY PER 100 LB. BODY WEIGHT, AND DIGESTIBILITY OF DRY MATTER AND PROTEIN

Hay no.	Intake	Coefficient of digestibility	
		Dry matter	Protein
	lb.	%	%
1	2.30	43.1	29.1
2	2.86	49.6	28.8
3	2.34	43.5	16.6
4	3.10	43.3	16.2
5	3.52	48.2	40.5
6	2.61	48.0	24.5
7	3.34	54.7	40.8
8	3.08	39.7	13.9
9	3.25	53.9	39.3
10	3.16	34.8	23.3
LSD, P=0.05	0.77	3.9	14.7

Relationships between chemical composition and (a) intake of hay per 100 lb. bodyweight, (b) digestibility of hay dry matter, and (c) coefficients of apparent digestibility of protein were measured by determining simple correlations (Snedecor, 1946). These correlation coefficients are given in table 3. There were positive correlations between intakes of the hays and their crude fiber contents ($P<0.05$) and intakes of the hays and their cellulose contents ($P<0.01$). On the other hand, the correlation coefficients show significant negative relationships between intakes of the hays and their contents of nitrogen-free extract, other carbohydrates, other carbohydrates less tannin or other carbohydrates less lignin and tannin. The correlation coefficients for protein, ether extract, ash, lignin, and tannin contents of the hays indicate that differences in intakes of the hays were not associated with these components.

Digestibility of dry matter and apparent digestibility of protein were positively correlated ($P<0.05$ and $P<0.01$, respectively) with crude fiber content of the hays. Significant negative correlations were found between (a) lignin content and digestibility of dry matter, and (b) lignin, nitrogen-free extract less tannin, other carbohydrates, and other carbohydrates less tannin and apparent digestibility of protein. However, sericea forage that is relatively high in digestibility and in crude fiber content may be low in productive value for livestock. This possibility is suggested by the finding that utilization of digested substances of feeds decreased as the crude fiber content increased (Kellner, 1915), by the rapid rate of decline in milk production of cows fed sericea regardless of its TDN content (Hawkins, 1958), and by the high proportion of acetate to propionate and butyrate found in rumen liquor from a steer fed sericea (unpublished results). The relatively high proportion of acetate to propionate and butyrate probably results in a high loss of energy, as Armstrong and Blaxter (1956) showed that the

heating effect is much greater for acetic acid than it is for either propionic or butyric acids.

The correlation coefficients, table 3, indicate that considerable progress may be made in developing a more palatable and more digestible sericea than current commercial strains by using chemical composition as a guide. Crude fiber was the only measured chemical component of the hays that was significantly correlated with all criteria evaluated, namely; amount of hay consumed, digestibility of dry matter and apparent digestibility of

TABLE 3. SIMPLE CORRELATIONS, COEFFICIENTS [a] BETWEEN CHEMICAL COMPOSITION, INTAKE, DIGESTIBILITY OF DRY MATTER AND APPARENT DIGESTIBILITY OF PROTEIN OF SERICEA HAYS

Chemical component	Hay intake per 100 lb. body wt.	Digestibility of	
		Dry matter	Protein
Crude protein	+0.22	−0.50	+0.05
Crude fiber	+0.67	+0.63	+0.74
Ether extract	−0.35	+0.18	+0.33
Ash	−0.09	−0.05	−0.10
NFE [b] less tannin	−0.64	−0.42	−0.72
Lignin	−0.38	−0.97	−0.82
Tannin	−0.40	−0.53	−0.39
O.C.[c]	−0.74	−0.43	−0.63
O.C. less lignin	−0.58	+0.23	−0.11
O.C. less tannin	−0.78	−0.33	−0.73
O.C. less lignin and tannin	−0.63	+0.15	−0.23
Cellulose	+0.77	+0.53	+0.60

[a] Least significant correlation coefficients, P=0.05 is 0.60 and P=0.01 is 0.74.
[b] NFE is nitrogen-free extract.
[c] See footnote (a), table 1.

protein. Hence, if only one component is to be measured, crude fiber would be expected to yield more information on these three criteria than the other entities, table 3. The positive relationships between crude fiber contents and desirable characteristics in sericea hays appear unusual. Nevertheless, evidence of differences in the relationships between the chemical composition and digestibility of dry matter for different plant species was presented by Phillips and Loughlin (1949). Also, an appraisal of 356 digestion coefficients of forages (Morrison, 1956) revealed that the digestibility of crude fiber was equal to or greater than that of nitrogen-free extract in approximately 36% of the cases. In addition, a recent study of sericea hays (McCullough *et al.*, 1953), showed the coefficient of digestibility of crude fiber was 55.3% as compared to 46.7% for nitrogen-free extract. Thus, there is evidence that in some forages high crude fiber content may lead to greater digestibility.

In view of the relationship between crude fiber and digestibility of dry matter, it seemed desirable to study this relationship in all sericea data from this laboratory. Digestibility and crude fiber data were available on

four additional sericea hays. With these data in the analyses making a total of 14 hays, the correlation between crude fiber content and digestibility of dry matter was +0.67. Thus the relationship is relatively constant.

The study of the relationship between lignin content of sericea forages and digestibility of dry matter of the forages was extended to include three additional sericea forages on which lignin content had been determined. One of the forages was sericea hay, another sericea leaves, and the third was sericea stems. The correlation between lignin content and digestibility of dry matter of the 13 sericea forages was —0.95. It is indicated therefore, that low lignin content in sericea, as in other forages (Phillips and Loughlin, 1949), is associated with more complete digestibility than is high lignin content.

There is a strong indication that the lignin values of the sericea forages do not represent true lignin. The lignin contents of sericea leaves, sericea stems, and sericea hay were 25.1, 15.8, and 20.8%, respectively. This relationship between apparent lignin contents of leaves and stems of sericea probably results from tannin interference with the lignin determination. In one study (Hawkins, 1955) modification of the lignin determination (Ellis *et al.*, 1946) by extracting tannin and correcting for undigested protein reduced the lignin value by 45.2%. Nevertheless, the phlobaphene formation during treatment of the samples with diluted H_2SO_4 indicated the presence of residual tannin in the extracted samples. Thus, the lignin values reported herein should be considered as apparent lignin rather than as true lignin. However, this discrepancy in the determination does not nullify the usefulness of lignin as an internal indicator for determining digestibility of sericea forage (Hawkins, 1958).

The correlation coefficients suggest that the soluble carbohydrates less tannin restrict consumption of sericea forage before crude fiber becomes a limiting factor. Probably the relationship between crude fiber content of sericea and palatability and digestibility are incidental. Most likely these relationships result from a decrease in the soluble fraction of sericea as the crude fiber content increases rather than from a beneficial effect of crude fiber *per se*. Since high crude fiber content is associated with low net energy value of forages (Kellner, 1915), a more palatable and more digestible sericea may have a low productive energy value.

It appears that maximum progress, in selecting individual plants for development of a more palatable and more digestible sericea variety, would be achieved by study of a combination of chemical components. Sericea plants highest in cellulose and lowest in lignin content would be expected to be highest in palatability and in digestibility, respectively. The high negative correlation between lignin content and digestibility of the forage appears to be quite consistent for a number of plant species (Phillips and Loughlin, 1949; Lancaster, 1943; Richards and Reid, 1952; Forbes and Garrigus, 1950). However, the complex and time consuming determination of lignin precludes its use in the screening of hundreds or thousands of in-

dividual strains of plants. For this reason, it is suggested that crude fiber content would be the most usable index in selecting sericea strains for digestibility of dry matter and apparent digestibility of crude protein. This approach, however, would not necessarily lead to the development of a sericea forage with a high productive energy value.

Summary

Ten sericea hays that differed significantly in amount consumed by dairy steers, in digestibility of dry matter, and in apparent digestibility of protein were studied to determine the correlations between these criteria of nutritive value and chemical composition. A positive relationship was found between the amounts of the hays consumed and their crude fiber and cellulose contents and between the digestibility of dry matter and the apparent digestibility of crude protein of the hays and their crude fiber contents. Other significant correlations, all negative, were between; (1) the amounts of forage consumed and contents of nitrogen-free extract less tannin, other carbohydrates, other carbohydrates less tannin and other carbohydrates less (tannin + lignin); (2) digestibility of dry matter of the hays and their lignin contents; and (3) apparent digestibility of protein of the hays and their contents of lignin, nitrogen-free extract less tannin, other carbohydrates, and other carbohydrates less tannin. Thus, the results of this study indicate that lignin was the chemical component of the hays that had the most adverse effect on digestibility, whereas, soluble carbohydrates other than tannin affected adversely the amount of hay consumed.

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USE OF THE ARTIFICIAL RUMEN TECHNIQUE TO ESTIMATE THE NUTRITIVE VALUE OF FORAGES [1]

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STUDIES on the role of rumen microorganisms in the nutrition of ruminant animals have led to the development of the "artificial rumen" or "in vitro" fermentation technique. Marston (1948) was probably the first to study the metabolism of rumen microorganisms by culturing the population of rumen microorganisms *in vitro* and determining the end products formed. The nutritional requirements of the rumen bacterial population have been studied by Burroughs *et al.* (1950a, 1950b, 1951), and Arias *et al.* (1951) with the result that rumen microorganisms have been shown to require (1) an anaerobic atmosphere, (2) minerals, (3) a source of ammonia nitrogen, (4) cellulose and (5) soluble carbohydrates. More recently it has been reported that the fatty acids, valeric and caproic (Bentley *et al.*, 1955) and the amino acids valine, proline, leucine and isoleucine (Dehority *et al.*, 1957) increased the rate of cellulose digestion in the artificial rumen.

Although the artificial rumen technique is currently being used extensively to study the nutritional requirements and the metabolism of rumen microorganisms, no comparisons have yet been reported on the response of rumen microorganisms *in vitro* and *in vivo* to a given dietary regimen. A close relationship between *in vitro* and *in vivo* responses should lend considerable reliability and usefulness to the artificial rumen technique.

The objectives of this paper are to compare the digestibility of forage cellulose *in vitro* and *in vivo* and to report the relationship between the digestible energy of a forage and its cellulose digestibility *in vitro*.

Experimental

Source, Preparation and Description of Forages. Relatively pure stands of Kentucky bluegrass, orchard grass, brome grass, timothy and alfalfa were established and harvested under similar conditions from May 20 to August 3, 1948 (Swift *et al.*, 1950). In a second experiment, six successive cuttings of orchard grass, three of timothy, two of brome grass and one each of Kentucky bluegrass and ladino clover were prepared under similar conditions from May 15 to October 10, 1950 (Swift *et al.*, 1952). The harvested forages were dried with forced air at 180° F. for 5 hours. At the time the forages were weighed for the digestion trial, laboratory samples were taken, ground in a large Wiley mill to pass through a sieve containing

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1.0-mm. diameter holes, and stored in glass-stoppered bottles sealed with beeswax. All samples were again ground in a small Wiley mill (30 mesh screen) prior to use in the artificial rumen.

In Vivo Sheep Digestion Trials. Thirty-five Hampshire wether lambs ranging in weight from 41 to 88 lb. were, on the basis of body weight, assigned to uniform groups of two to four, usually four animals per group. In most of the digestion periods, sheep within a group received identical quantities of feed. Each 11-day total collection period was preceded by a period of 14 days, the first 7 of which were a transition period followed by a 7-day preliminary period.

The digestion coefficients and digestible energy of the above forages were reported by Swift *et al.* (1950, 1952). The cellulose digestibility of these same forages in the same digestion trials were reported by Sullivan (1955). Cellulose was determined on the feed and feces by the Kuerschner and Hanak method as modified by Phillips and Smith (1943).

In Vitro Digestion Trials. The artificial rumen procedure used was somewhat similar to that reported by Bentley *et al.* (1955) and may be described as follows:

Ten artificial rumen flasks, containing 1.0 gm. cellulose (Alphacel) or 3.0 gm. forage, 0.3 gm. urea, 40 ml. mineral mixture (Bentley *et al.*, 1955), 2.0 ml. each of iron, calcium and sodium carbonate solutions (Bentley *et al.*, 1955) and 65 ml. distilled water, were placed in a thermostatically controlled water bath at 39.0±0.1° C. and carbon dioxide was bubbled through each flask for at least 30 min. to flush the system of oxygen while the inoculum was being obtained. The inoculum, 75 ml. of rumen juice, was obtained by suction from two rumen-fistulated sheep and strained through four layers of chesecloth prior to its addition to each flask. The inoculum was obtained prior to the morning feeding between 9:00 and 9:30 a.m. from each of two sheep fed 1½ lb. of good quality, second cutting alfalfa hay twice a day. The water intake on the morning of sampling was controlled by giving each sheep approximately 3 liters of water at the evening feeding (5:00 p.m.) and no water in the morning prior to sampling.

The pH of the fermentation medium was adjusted to 6.95 with saturated sodium carbonate solution at the start of the fermentation. Each flask was individually gassed with carbon dioxide during the entire fermentation period. In the initial series of fermentations, the pH of the medium was checked periodically throughout the fermentation period; but since it was found that the pH did not drop below 6.7 during a 24-hour fermentation period, succeeding fermentations were not disrupted for pH determinations.

Following the 24-hour fermentation period, the volume of the medium was adjusted to 200 ml. and duplicate aliquots were taken for cellulose determinations by the method of Crampton and Maynard (1938). A modification consisted of digesting the mixture in a boiling water bath for 20 min. rather than refluxing.

Since it is well established that small amounts (approximately 0.1%)

of soluble carbohydrates stimulate cellulose digestion *in vitro* (Arias *et al.*, 1951), 0.2 gm. glucose was added to the flask containing purified cellulose to provide for rapid cellulose digestion, but was omitted from flasks containing forage since all the forages tested contained more than 35% nitrogen-free extract.

Statistical methods were those described by Snedecor (1956).

Results and Discussion

The problems of substrate concentration and fermentation time *in vitro* are inherent in a comparison of forage cellulose digestibility by *in vitro* and *in vivo* techniques. Kamstra *et al.* (1958), using an artificial rumen system similar to that used in these experiments, observed that more cellulose was digested in the artificial rumen with increasing levels of cellulose in the medium, but that the percent cellulose digested remained essentially constant and characteristic of the availability of the cellulose in the substrate, provided the substrate concentration ranged from 0.3 to 0.8%.

Since the 35 forages used in these experiments varied in cellulose content from 22 to 36% and since the results of Kamstra *et al.* (1958) indicated

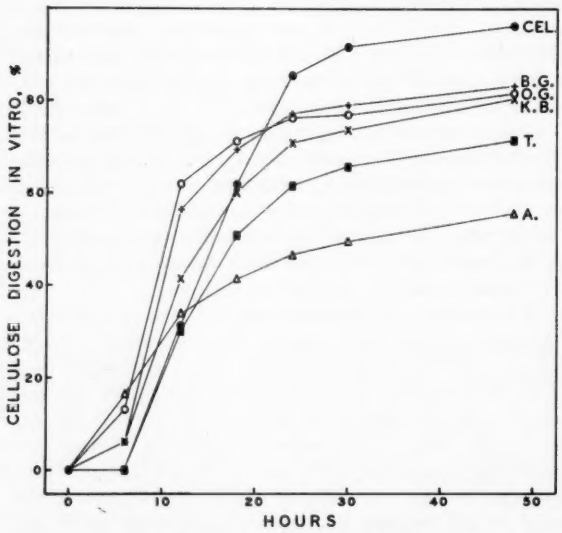

Figure 1. The effect of fermentation time on the rate of cellulose digestion in brome grass, orchard grass, Kentucky bluegrass and timothy harvested at the early head stage of maturity compared with purified cellulose (Alphacel) and second-cutting alfalfa.

that cellulose concentration *in vitro* was not critical, a constant amount of forage (3.0 gm. per 200 ml. fermentation medium) was added to each flask instead of a constant amount of cellulose. This was done to minimize the possible effect of other factors such as protein, nitrogen-free extract and ash on the rate of cellulose digestion. In each fermentation period, purified cellulose was added to one flask at the 0.5% level to obtain a measure of the activity of the rumen microorganisms to a readily available form of cellulose.

An experiment was performed to determine the length of time the forages should be fermented in the artificial rumen (figure 1). The four grasses, brome grass, orchard grass, Kentucky bluegrass and timothy were

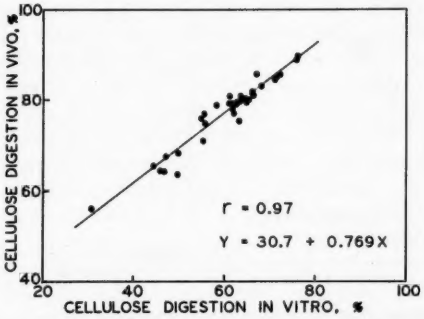

Figure 2. Regression of percent cellulose digested in vivo on percent cellulose digested in vitro.

cut at the same stage of maturity (early head) between May 15 and June 6. Alfalfa was second cutting harvested July 20. The results show a variable lag period followed by a rapid rate of cellulose digestion 6 to 18 hours after the start of the fermentation. At 18 hours, the rate of digestion slowed down so that only about 5 to 10% more cellulose digestion was obtained at 48 hours than at 24 hours. Since 24-hour fermentation gave essentially the same relative percent cellulose digestion as 48-hour, a 24-hour fermentation period was chosen for succeeding experiments. Furthermore, a 24-hour period might be more nearly like conditions found in the animal, for mixed bacterial populations tend to change over a long fermentation period.

The cellulose digestibility of the 35 forages in the animal and in the artificial rumen are compared in figure 2. Each point is an average of two to four, usually four, animal trials and two artificial rumen trials.

The correlation coefficient of +0.97 is indicative of the close relationship between the values obtained in the artificial rumen and those obtained in the animal. Furthermore, the relationship appears to be linear throughout the range of values used in these experiments. This highly significant

correlation furnishes strong evidence for the reliability and usefulness of the artificial rumen technique. Because of the close relationship, a prediction equation was calculated from the data, namely, $Y=30.7+0.769\ X$, in which the cellulose digestion coefficient (Y) in the animal may be calculated from the percent cellulose digested (X) in the artificial rumen. Using this equation the standard deviation of a predicted Y is 2.05 with a coefficient of variation of 2.66%.

This close relationship suggested that the variability associated with both *in vivo* and *in vitro* digestion trials should be estimated. The vari-

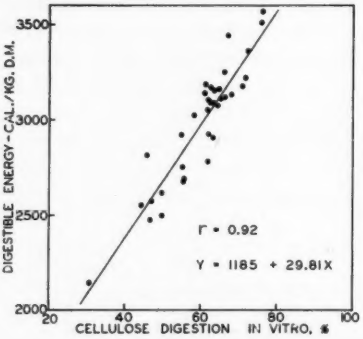

Figure 3. Regression of experimentally determined digestible energy on percent cellulose digested in vitro.

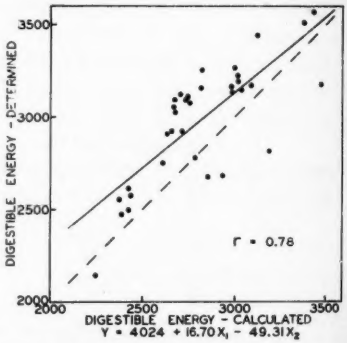

Figure 4. Regression of experimentally determined digestible energy on calculated digestible energy (Axelsson-Reid-Swift formula).

ability in the percent cellulose digested in the artificial rumen was determined by including a sample of purified cellulose (Alphacel) and a sample of timothy hay in each of 15 fermentation periods. For purified cellulose, the mean percent cellulose digested in 24 hours was 80.54% with a standard deviation of 3.63. For timothy hay, the mean percent cellulose digested was 50.01 with a standard deviation of 1.90. Furthermore, when the two replicates of the 35 forage samples were analyzed statistically, the standard deviation and the coefficient of variation of replicate determinations were found to be 1.30 and 2.19%, respectively. Similarly, the variability of a single digestion trial was calculated from the 35 digestion trials in which two to four, usually four sheep were used per trial. The results showed a mean cellulose digestion coefficient of 77.14%, a standard deviation of 1.44 and a coefficient of variation of 1.86%. It would appear from these results that the variability associated with cellulose digestibility *in vivo* is only slightly smaller than the variability associated with replicate determinations of cellulose digestibility in the artificial rumen.

Because of the close relationship between *in vivo* and *in vitro* cellulose digestibility, and since it is known that cellulose digestibility in the animal is significantly correlated with TDN or digestible energy, the relationship between cellulose digestibility *in vitro* and digestible energy was investigated. The results presented in figure 3 show a highly significant relationship ($r=+0.92$) between the cellulose digested *in vitro* and the digestible energy of the forage. This correlation is of the same order of magnitude as the correlation between percent lignin and digestible energy ($r=-0.91$) in these same forages. In other words, in the 35 forages tested, cellulose digestion in the artificial rumen gave as good an estimate of the nutritive value of the forage as the amount of lignin it contained. Calculation of a prediction equation from the data results in $Y=1185+29.81X$ where Y is the digestible energy of the forage in Calories per kilogram dry matter and X is the percent cellulose digested in the artificial rumen. Using this equation, the standard deviation of a predicted Y is 125 Calories per kilogram dry matter with a coefficient of variation of 4.20%.

Since variability is also associated with digestible energy determinations, the variability of a single digestion trial was determined on the 35 forages. It was found that the standard deviation of a single digestion trial in which four sheep were used per trial was 59 Calories per kilogram dry matter, with a coefficient of variation of 1.98%. It may be observed that this variability is only slightly smaller than the variability associated with replicate determinations of cellulose digestibility *in vitro*.

Probably the best formula that has been published to estimate the available energy in a forage from the protein and crude fiber content is that of Axelsson (1953). Schneider's formulas (1951, 1952) require a complete proximate analysis for energy estimation whereas Morrison's tables (1956) are not as versatile since they represent averages of varying protein, crude fiber and energy content and digestibility. Lignin content has been shown by some workers to be significantly correlated with energy or organic matter digestibility (Phillips and Loughlin, 1949; Forbes and Garrigus, 1950; Walker and Hepburn, 1955; Sullivan, 1955; Meyer and Lofgreen, 1956), whereas other workers found little correlation in this respect (Heller and Wall, 1940; Crampton and Jackson, 1944; and Crampton, 1957). Significant correlations have also been obtained between crude fiber content and organic matter digestibility by some workers (Axelsson, 1950; Walker and Hepburn, 1955; Meyer and Lofgreen, 1956) but not by others (Heller and Wall, 1940; Crampton and Jackson, 1944). These observed differences may be due to species differences for Phillips and Loughlin (1949) and Sullivan (1959) have observed different regression equations for different species of forages, e.g. alfalfa, timothy and reed canary grass. Furthermore, Pigden (1953) observed that the progress and site of lignification were not similar in the various range grasses which were studied.

Axelsson's (1953) formula estimates the metabolizable energy from the

digestible protein and the crude fiber content. Therefore, in order to use the formula to estimate the digestible energy of a forage from the crude protein and crude fiber content of the dry matter, several substitutions have to be made into the formula. Substituting Reid's (1958) formula for converting crude protein to digestible protein and Swift's (1957) factor for converting digestible energy to metabolizable energy into Axelsson's formula for estimating metabolizable energy from the digestible protein and crude fiber content of the forage dry matter results in the following relationship: $Y=4024+16.70\ X_1-49.31\ X_2$ where Y is the digestible energy in Calories per kilogram dry matter, X_1 is the percent protein in the dry matter, and X_2 is the percent crude fiber in the dry matter.

When the formula is used to estimate the digestible energy of the 35 forages used in this experiment, the relationship between the estimated and

TABLE 1. PREDICTION EQUATIONS AND VARIABILITY FOR ESTIMATING NUTRITIVE VALUE OF FORAGES FROM *IN VITRO* TECHNIQUES AND FORAGE COMPOSITION DATA

Relationship				
Y	X	Regression equation	Standard deviation	Coefficient of Variation
Percent cellulose digested *in vivo*	Percent cellulose digested *in vitro*	$Y=30.7+0.769X$	2.05	2.66
Digestible energy	Percent cellulose digested *in vitro*	$Y=1185+29.81X$	125	4.20
Digestible energy	Axelsson-Reid-Swift formula	$Y=4024+16.70X_1+49.31X_2$	194	6.47

the determined digestible energy is shown in figure 4. The correlation coefficient (+0.78) shows that this formula does not give as good an estimate of the experimentally determined digestible energy as the cellulose digestibility obtained *in vitro*. However, because of the variability of the data, the experimentally determined values (solid line) are not significantly different from the theoretical calculated values (broken line). In other words, although Axelsson's formula somewhat underestimated the digestible energy of most of the forages used in these experiments, the underestimation was not statistically significant. Furthermore, using the Axelsson-Reid-Swift formula to calculate the digestible energy of the 35 forages, the standard deviation of a predicted Y is 194 Calories per kilogram dry matter and the coefficient of variation is 6.47%.

Table 1 summarizes the prediction equations and the variability associated with each. It may be observed that the digestible energy of a forage is more closely associated with its digestible cellulose *in vitro* than with its crude protein and crude fiber content. This is in agreement with the concept that the nutritive value [2] of a forage is more closely associated with the

[2] Nutritive value may be considered as the energy gained per animal per day when the animal consumes *ad libitum* the entire ration under controlled conditions.

digestibility of its major energy-yielding nutrient (cellulose) than with its protein and crude fiber content.

Conventional digestion trials and 24-hour *in vitro* cellulose digestibility trials estimate the digestible or available energy of forages per unit dry matter. According to Crampton's (1957) hypothesis, digestible energy, which is an index of completeness of energy digestion, is not the most reliable index of forage nutritive value.

Crampton (1957) suggested that voluntary consumption would provide a better index of forage "feeding value", and that "voluntary consumption is limited primarily by rate of digestion of its cellulose and hemicellulose". If this is true, the artificial rumen might be a useful, reliable tool to estimate both the completeness of energy digestion, by determining the cellulose digestibility in a 24-hour fermentation period, and the voluntary consumption, by determining the rate of cellulose digestion by rumen microorganisms *in vitro*.

It is postulated that a combination of estimates of both voluntary consumption and completeness of energy digestion would give a better estimate of forage nutritive value than either the total digestible nutrients system or the digestible energy system currently being used. Investigations are now underway to test this hypothesis.

Summary

A comparison has been made of the cellulose digestibility of 35 forages *in vitro* and *in vivo*. The *in vitro* system utilized ovine rumen microorganisms, all-glass fermentation vessels, and a 24-hour fermentation period, whereas the *in vivo* system utilized conventional 11-day digestion trials with two to four, usually four, sheep per trial. The forages tested were orchard grass, brome grass, Kentucky bluegrass, timothy, alfalfa and ladino clover. The correlation coefficient of +0.97 indicates a close, linear relationship between cellulose digestion *in vitro* and *in vivo*.

Cellulose digestion *in vitro* was also significantly correlated ($r=+0.92$) with the digestible energy of these same forages. This correlation was considerably better than the correlation between determined digestible energy and calculated digestible energy by the Axelsson-Reid-Swift formula ($r=+0.78$).

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SARCOSINE AND CREATINE AS NITROGEN SOURCES FOR THE RUMINANT, AND THE INFLUENCE OF SUPPLEMENTAL VITAMIN B_{12}

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IN view of the restrictions imposed upon the present day feeding of non-protein nitrogen (NPN) to ruminants, considerable attention has been directed toward finding new nitrogen sources or to improve upon the utilization of those presently available. This study was designed to compare urea with creatine and sarcosine (N-methyl glycine) for such a purpose.

Dubos and Miller (1937) have shown four different types of soil bacteria to contain enzyme systems capable of decomposing creatine or its anhydride, creatinine. Subsequent studies with these soil bacteria by Krebs and Eggleston (1939) and Akamatsu and Miyashita (1951) disclosed that these enzymes are totally adaptive and that the optimal pH and temperature necessary for maximal degradation of creatine are quite similar to those in the rumen. The end products of creatine decomposition by these bacteria have been identified as urea and sarcosine. In addition, the *in vitro* studies of Belasco (1954) suggest that creatine may be an effective nitrogen source for rumen microorganisms as measured by its support of cellulose digestion.

On the basis of these findings, it was felt that creatine and sarcosine might be more satisfactory sources of nitrogen than urea for protein synthesis by rumen microorganisms *in vivo*. The influence of supplemental vitamin B_{12} was studied also, because of the possibility of increased need for this vitamin in the metabolism of these NPN materials in the lambs.

Experimental

Four separate digestion and nitrogen metabolism trials were conducted with wether limbs averaging approximately 30 kg. in weight. Semi-purified rations containing 4.5 ppm of cobalt chloride and 1.7% nitrogen were used. Two-thirds of the total ration nitrogen was supplied by urea or creatine or by combinations of urea and creatine or sarcosine. The constituents and composition of these rations are shown in tables 1 and 2. All ingredients except the wheat straw and molasses were contained in a concentrate mixture. In order to make all rations as nearly iso-nitrogenous and iso-

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caloric as possible, the amount of dextrose was varied with the addition of creatine or sarcosine. The lambs were fed equal amounts of the ration daily and at each feeding the wheat straw, molasses, and concentrate were mixed individually for each animal.

The standard digestion and nitrogen metabolism procedures followed in the conduct of these trials have been described by Anderson *et al.* (1959).

TABLE 1. CONSTITUENTS AND AVERAGE COMPOSITION OF DAILY RATIONS FED IN TRIALS 1 AND 2

Item	Rations according to percent of NPN supplied by creatine						
	0	2.5	7.5	15.0	33.0	67.0	100
Ration constituents, gm.							
Wheat straw	400.0	400.0	400.0	400.0	400.0	400.0	400.0
Cane molasses (78% solids)	170.0	170.0	170.0	170.0	170.0	170.0	170.0
Concentrate mixture	220.0	220.0	220.0	220.0	220.0	220.0	220.0
Purified soybean protein [a]	14.5	14.5	14.5	14.5	14.5	14.5	14.5
Corn starch	83.6	83.6	83.6	83.6	83.6	83.6	83.6
Dextrose	35.8	35.7	35.2	34.6	33.0	30.3	27.5
Corn oil	32.3	32.3	32.3	32.3	32.3	32.3	32.3
Mineral mixture [b]	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Vitamin A-D oil [c]	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Urea	20.2	19.6	18.6	17.1	13.6	6.9	.....
Creatine [d]	.....	0.7	2.2	4.3	9.4	18.8	28.5
Choline	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Vitamin supplement [e]	*	*	*	*	*	*	*
Composition, dry-matter basis, %							
Organic matter	93.30	93.17	93.08	93.15	93.15	93.19	93.12
Protein (N X 6.25)	11.20	11.23	11.12	11.07	10.90	10.72	10.91
Ether extract	5.45	5.45	5.46	5.46	5.45	5.43	5.42
Crude fiber	23.40	23.36	23.34	23.35	23.37	23.40	23.44
N-free extract	53.25	53.13	53.16	53.27	53.43	53.64	53.35

[a] Drackett Assay Protein C-1. The Drackett Products Company, Cincinnati 32, Ohio.
[b] Thomas *et al.* J. Nutr. 43:515 (1951).
[c] Nopco XX. National Oil Products Company, Harrison, New Jersey. Stated to contain no less than 2250 USP units of vitamin A and 300 IC units of vitamin D per gram.
[d] Creatine contained 32% nitrogen and was generously supplied by the Allied Chemical and Dye Corporation, New York, New York.
[e] The daily concentrate mixture furnished 1.8 mg. each of thiamine and riboflavin and 8.0 mg. of alpha tocopherol. These materials and vitamin B_{12} were supplied by Merck, Sharp and Dohme, Inc., Rahway, New Jersey.

The analyses of urine, feces, and feed were carried out according to A.O.A.C. (1950) procedures.

Urinary creatine and creatinine were determined by the procedure of Clark and Thompson (1949). The analysis for fecal creatine was carried out by extracting the feces with hot 2N sulfuric acid. The extraction mixture was then filtered and the filtrate treated according to the procedure of Clark and Thompson (1949).

The values used in calculating the metabolic fecal nitrogen and the endogenous urinary nitrogen required in the Thomas-Mitchell equation were 0.435 gm. N per 100 gm. dry matter intake and 0.034 gm. N per kg. body weight, respectively. These values were obtained in this laboratory with lambs fed a low-nitrogen ration (0.26%N) containing wheat straw as the sole roughage (McLaren *et al.*, 1956).

During a 5-day pre-preliminary period all lambs were adjusted to a constant daily feed intake which was maintained throughout each trial. Collection periods were of 10 days duration and were preceded by one or more 10-day preliminary periods.

Trials 1 and 2. Creatine was fed at seven levels of supplementation: 0, 2.5, 7.5, 15, 33, 67, and 100% of the ration non-protein nitrogen with urea

TABLE 2. CONSTITUENTS AND AVERAGE COMPOSITION OF DAILY RATIONS FED IN TRIALS 3 AND 4

Item	Rations according to NPN source			
	100% Urea	33% Creatine	100% Urea	33% Sarcosine
Trial number	3	3	4	4
Ration constituents, gm.				
Wheat straw	400.0	400.0	400.0	400.0
Cane molasses (78% solids)	170.0	170.0	170.0	170.0
Concentrate mixture	200.0	200.0	200.0	200.0
Purified soybean protein	13.2	13.2	13.2	13.8
Corn starch	76.0	76.0	76.0	79.8
Dextrose	32.6	30.1	32.6	22.9
Corn oil	29.4	29.4	29.4	30.9
Mineral mixture	27.2	27.2	27.2	28.6
Vitamin A-D oil	2.6	2.6	2.6	2.7
Urea	18.4	12.3	18.4	12.9
Creatine	—	8.6	—	—
Sarcosine[a]	—	—	—	17.7
Choline	0.6	0.6	0.6	0.7
Vitamin supplement[b]	*	*	*	*
Composition, dry matter basis, %				
Organic matter	92.94	92.87	93.35	93.26
Protein (N X 6.25)	10.56	11.01	11.40	11.79
Ether extract	5.31	5.30	5.30	5.43
Crude fiber	23.19	23.22	24.08	23.79
N-free extract	53.88	53.34	52.57	52.25

[a] Sarcosine contained 15.7% nitrogen and was generously supplied by the Allied Chemical and Dye Corporation, New York, New York.

[b] The daily amount of concentrate furnished 1.8 mg. each of thiamine and riboflavin and 8.0 mg. of alpha tocopherol. In addition, half of the lambs which were fed each of the above rations received 10 mcg. of vitamin B_{12} daily in the vitamin supplement.

supplying the remainder. These rations are described in table 1. Two lambs were subjected to each treatment. In Trial 2 the lambs were randomized again and the same feeding design was followed except that each lamb received 10 mcg. of vitamin B_{12} daily. In each of these trials a 10-day preliminary period was followed by a 10-day collection period.

Trial 3. In this trial eight lambs received a ration in which urea was the only source of supplementary NPN and eight others received a ration in which 33% of the supplementary NPN was supplied by creatine and the remainder by urea. These rations are described in table 2. Within each

NPN group four lambs received 10 mcg. of supplementary vitamin B_{12} daily and four did not. Trial 3 consisted of a 10-day preliminary period followed by two successive 10-day collection periods.

Trial 4. The design of this trial was identical to that of Trial 3 except that sarcosine replaced creatine as a source of nitrogen. The rations used in Trial 4 are described in table 2. Trial 4 involved a 10-day preliminary period followed by two successive 10-day collection periods.

All results were tested for significance by analysis of variance as described by Snedecor (1956).

Results

Nutrient digestibility and nitrogen metabolism data obtained in Trials 1 and 2 are given in table 3. Each figure represents the mean value obtained with four lambs from the pooled data of both trials. Statistical analysis of these data revealed that the 7.5% and 15% levels of creatine supplementation significantly improved ($P<.05$) the digestibility of organic matter and N-free extract over that obtained with the urea control lambs. At the 33% creatine level the improvement in digestibility of organic matter, crude fiber, and N-free extract was highly significant ($P<.01$). However, no level of creatine exerted a significant effect upon protein digestibility or nitrogen utilization; thus, in these respects, creatine and urea were equivalent.

During the collection period of Trial 1 some difficulty was encountered in obtaining satisfactory feed consumption by lambs fed the creatine supplemented rations. The addition of 10 mcg. of vitamin B_{12} to the daily ration during Trial 2 resulted in a marked improvement in the appetite.

The design of Trials 1 and 2 was such that the effects of vitamin B_{12} and

TABLE 3. EFFECT OF VARIOUS LEVELS OF CREATINE ON DIGESTIBILITY AND NITROGEN METABOLISM IN TRIALS 1 AND 2 [a]

Item	Creatine level as percent of NPN						
	0	2.5	7.5	15.0	33.0	67.0	100
Dry matter intake, gm.	703.0	704.4	705.0	704.7	704.1	703.2	701.9
Ration protein (N X 6.25), %	11.2	11.2	11.1	11.1	10.9	10.7	10.9
Av. digestion coefficients							
Organic matter	59.1	58.8	61.2*[b]	61.5*	62.9**	59.1	60.7
Protein	68.0	70.4	69.0	69.6	69.8	66.5	66.9
Crude fiber	42.4	39.9	45.9	45.6	48.1**	43.0	45.8
N-free extract	62.1	62.2	64.2*	64.4*	65.9**	62.2	63.7
Nitrogen metabolism							
Nitrogen intake, gm.	12.6	12.4	12.5	11.9	12.0	11.9	12.3
Fecal nitrogen, gm.	4.0	3.7	3.9	3.6	3.6	3.8	4.1
Urinary nitrogen, gm.	7.8	7.9	7.8	7.6	6.8	7.5	7.4
Nitrogen balance, gm.	0.7	0.9	0.8	0.7	1.6	0.4	0.8
Retained nitrogen, gm.[c]	4.8	4.9	4.9	4.7	5.6	4.5	4.9
Absorbed N retained, %	41.0	41.3	41.4	41.8	49.2	40.6	43.8

[a] All values are on an average daily basis.
[b] All statistical comparisons were made with zero % creatine.
[c] Nitrogen balance plus metabolic fecal N plus endogenous urinary N.
* $P<.05$.
** $P<.01$.

of time upon nutrient digestibility and nitrogen utilization could not be separated. For this reason Trial 3 was designed specifically to test these effects with urea and the creatine-urea mixture as sources of NPN.

In table 4 are shown the results of Trial 3 as represented by the pooled data from both collection periods. Each figure represents the mean value obtained with eight lambs in each treatment over the entire 20-day period. The addition of vitamin B_{12} to the urea or the creatine and urea rations

TABLE 4. THE EFFECT OF CREATINE AND VITAMIN B_{12} UPON DIGESTIBILITY AND NITROGEN METABOLISM IN TRIAL 3 [a]

Item	Urea		Creatine	
	Without B_{12}	With B_{12}	Without B_{12}	With B_{12}
Dry matter intake, gm.	685.5	685.4	684.6	684.7
Ration protein (N X 6.25), %	10.6	10.8	10.6	11.0
Av. digestion coefficients				
Organic matter	62.7	63.7	60.5	63.7*
Protein	68.5	71.9**	66.0	70.9**
Crude fiber	45.4	47.7	46.6	47.7*
N-free extract	68.2	67.0	65.6	67.1
Nitrogen metabolism				
Nitrogen intake, gm.	11.6	12.0	11.4	12.0
Fecal nitrogen, gm.	3.6	3.3	3.9	3.5
Urinary nitrogen, gm.	7.3	7.7	7.1	7.2
Nitrogen balance, gm.	0.6	1.0	0.4	1.4
Retained nitrogen, gm.[b]	4.6	5.0	4.3	5.4
Absorbed N retained, %	42.4	42.8	42.0	46.6

[a] All values are on an average daily basis and represent the pooled data from two consecutive 10-day periods.
[b] Nitrogen balance plus metabolic fecal N plus endogenous urinary N.
* $P<.05$.
** $P<.01$.

resulted in a highly significant ($P<.01$) improvement in protein digestibility. Supplemental vitamin B_{12} also significantly improved ($P<.05$) the digestibility of organic matter and crude fiber, but only in the creatine-containing rations. The retention of absorbed nitrogen from the creatine ration was also improved by vitamin B_{12} but the effect was not significant. A separate comparison of the nitrogen metabolism data obtained with the urea rations, with and without B_{12}, revealed that B_{12} had no effect upon the retention of absorbed nitrogen.

When each 10-day period of Trial 3 was considered individually, vitamin B_{12} was shown to result in a significant improvement ($P<.05$) in nitrogen utilization during the first 10 days of the trial. This improvement was associated mainly with those lambs receiving the creatine rations. The comparison of individual 10-day periods also revealed that

a highly significant increase ($P<.01$) in the retention of absorbed nitrogen occurred as a direct result of time.

The pooled results from both collection periods of Trial 4 are shown in table 5. Each figure represents the mean value obtained with eight lambs. These results show that sarcosine, when compared with urea, had no effect upon the digestibility of ration nutrients or the percent of

TABLE 5. THE EFFECT OF SARCOSINE AND VITAMIN B_{12} UPON DIGESTIBILITY AND NITROGEN METABOLISM IN TRIAL 4 [a]

Item	Urea		Sarcosine	
	Without B_{12}	With B_{12}	Without B_{12}	With B_{12}
Dry matter intake, gm.	686.9	686.2	696.5	695.3
Ration protein (N X 6.25), %	11.4	10.9	11.3	11.8
Av. digestion coefficients				
Organic matter	62.4	64.2	63.3	64.7
Protein	71.0	73.0**	70.6	75.0**
Crude fiber	48.3	50.8	47.4	50.8*
N-free extract	65.1	66.7*	66.7	66.7
Nitrogen metabolism				
Nitrogen intake, gm.	12.5	11.9	12.3	13.1
Fecal nitrogen, gm.	3.6	3.2	3.6	3.3
Urinary nitrogen, gm.	6.7	6.8	6.7	7.4
Nitrogen balance, gm.	2.2	1.9	2.5	1.9
Retained nitrogen, gm.[b]	6.2	6.0	5.9	6.5
Absorbed N retained, %	52.1	50.9	50.8	50.6

[a] All values are on an average daily basis and represent the pooled data from two consecutive 10-day periods.
[b] See table 4.
* $P<.05$.
** $P<.01$.

absorbed nitrogen retained. Vitamin B_{12} supplementation produced a highly significant ($P<.01$) increase in protein digestibility in both the urea- and sarcosine-fed lambs and a signficant ($P<.05$) increase in crude fiber digestibility with sarcosine-fed lambs and a significant ($P<.05$) increase in N-free extract digestibility in the urea-fed lambs. These effects are similar to those observed in Trial 3 with creatine.

To evaluate further the availability of creatine nitrogen, the urine from each lamb in Trials 1, 2, and 3 and the feces from each lamb in Trial 1 were quantitatively assayed for creatine. In Trial 1 no differences were found between the fecal or urinary excretion of lambs fed urea and those fed the various levels of creatine. Similarly, in Trial 2 there were no differences in the urinary excretion between the urea- and the creatine-fed lambs. In Trial 3, creatine feeding significantly ($P<.05$) increased the amount of this compound in the urine. However, it should be pointed out that this increase was of a relatively small magnitude in terms of the

amount of creatine consumed. During Trial 3 each lamb received approximately 9 gm. of creatine daily. The average daily excretion of these lambs was 1.79 gm. and that of the urea-fed lambs was 1.52 gm.

During these trials no toxic or deleterious effects were observed as a result of feeding either urea, creatine, or sarcosine.

Discussion

On the basis of the results which have been presented, creatine and sarcosine appear to be satisfactory nitrogen sources for the ruminant. When fed at the 33% level of NPN supplementation, both creatine and sarcosine are as effective as urea in terms of the digestibility of ration nutrients and the utilization of ration nitrogen. Creatine was also as effective as urea at levels of supplementation up to 100% of the dietary NPN.

In addition to the digestion and nitrogen metabolism data obtained in these experiments, the fact that only a small part of the ingested creatine could be recovered from the urine or feces of the lambs also indicates its utilization by the rumen microflora. As might be expected, this does not occur in the case of the non-ruminant. Foster and Fisher (1911) have shown large increases in excretion after the administration of creatine to dogs. Lyman and Trimly (1917) have observed the same pattern in rabbits injected with creatine. Maw (1948) demonstrated a quantitative excretion of creatine when fed to rats. Chanutin (1926) and Myers and Fine (1915) have shown that creatine fed to humans is excreted as creatinine in the urine.

The decomposition of creatine within the rumen presumably results in the production of sarcosine and urea. This metabolic pattern has been established in soil bacteria by Krebs and Eggleston (1939) and Akamatsu and Miyashita (1951). The urea produced from the breakdown of creatine could then be utilized by the rumen microorganisms following the action of urease. The sarcosine moiety could also be readily available to the microorganisms as is shown in Trial 4. One of the most interesting features of this sequence of reactions is the possibility it presents with regard to feeding higher levels of dietary NPN without encountering toxic effects. That is, if the rate of creatine decomposition is slower than the rate of urease action, then the production of ammonia may be at a rate which is slow enough to permit more efficient use by the rumen microflora.

The necessity of allowing sufficient time in order to attain maximum utilization of ration nutrients by the ruminant animal has, of course, been recognized for some time. However, the period difference observed in Trial 3 emphasizes not only the adaptive nature of the rumen microbial population or of the enzyme system responsible for the decomposition of creatine, but also the desirability of employing preliminary feeding periods of longer duration than the conventional 10-days. This would be

particularly true in the case of semi-synthetic rations containing relatively high levels of NPN.

These findings are in accord with the reports of Repp (1954), Smith *et al.* (1957), and Welch *et al.* (1957) who also advocate longer preliminary feeding periods to insure complete adjustment or adaptation. The absence of a period difference or adaptation effect in Trial 4 may be attributed to the fact that this experiment was immediately preceded by Trial 3. This allowed adequate time prior to Trial 4 for a complete adaptation to occur. This fact may also account for the high percentage of absorbed nitrogen which was retained in Trial 4.

At present it is generally agreed that rumen microorganisms will synthesize sufficient vitamin B_{12} to meet the animal's requirement if adequate amounts of cobalt are available. However, it was observed in these studies that supplemental vitamin B_{12} markedly improved the digestibility of ration constituents and nitrogen utilization, particularly in the case of creatine-fed lambs during the early stages of NPN supplementation. It was also interesting to note that the alacrity of appetite was improved markedly when vitamin B_{12} was included in the creatine rations. This effect was also noted in the urea-fed lambs, but the response was not so great as when creatine was fed.

The beneficial effects of vitamin B_{12} observed in this study suggests that the creatine-fed lambs were unable to synthesize adequate amounts of this vitamin. The basis for this possible insufficiency may be due to a decrease in B_{12} synthesis by the rumen flora and/or an increased requirement for the vitamin resulting from the metabolism of creatine or its hydrolytic products. The work of Pearson *et al.* (1953) has clearly pointed out that the synthesis of vitamin B_{12} is markedly decreased when semi-purified rations are substituted for natural feedstuffs. Thus, it may be that the effects of supplementary vitamin B_{12} resulted from the inability of the rumen microorganisms to synthesize the vitamin at a rate commensurate with the B_{12} requirement, particularly during the early stages of adaptation. This condition apparently exists even though sufficient amounts of cobalt are available. In this respect, a consideration of the known metabolic roles played by vitamin B_{12} emphasizes its function in the biosynthesis of labile methyl groups. Conceivably then, vitamin B_{12} may be needed for the proper metabolism of sarcosine when this compound is fed or when it arises from the breakdown of creatine. If this is true, then the actual requirement for vitamin B_{12} is increased by the feeding of creatine or sarcosine.

Summary

Creatine and sarcosine, alone and in combination with urea and vitamin B_{12}, were compared with urea as nitrogen sources for the ruminant. Four digestion and nitrogen metabolism trials were conducted with wether lambs fed semi-purified rations containing 4.5 ppm of cobalt chloride

and 1.7% nitrogen. In these rations urea or creatine and combinations of urea and sarcosine or creatine furnished 67% of the total ration nitrogen.

In the first two trials creatine was fed at levels of 0, 2.5, 7.5, 15, 33, 67, and 100% of the supplementary ration NPN with urea supplying the remainder. At all levels of supplementation creatine was equal to, or more effective than, urea in terms of nutrient digestibility and nitrogen utilization.

Two successive 10-day collection periods were used in Trials 3 and 4 to compare 33% creatine-N replacing urea and 33% sarcosine-N replacing urea with 100% urea-N. In both trials, each NPN source was fed with and without vitamin B_{12}. The nitrogen from the rations containing creatine and sarcosine was utilized as effectively as the nitrogen from the urea ration. Vitamin B_{12} markedly improved the digestibility of organic matter, crude protein, and crude fiber. When fed with creatine, vitamin B_{12} was effective in promoting an increased retention of absorbed nitrogen, particularly during the early stages of adaptation by the rumen microorganisms to the creatine substrate.

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GENERAL AND SPECIFIC COMBINING ABILITY FOR 154-DAY WEIGHT AMONG THREE-LINE CROSSES IN SWINE [1]

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EXPERIENCE in developing inbred lines of swine indicates that selection is usually not completely effective in preventing some deterioration in litter size, vigor and other components of performance (Dickerson *et al.*, 1954; Donald, 1955; Bradford *et al.*, 1958). Craft (1953) summarized a number of studies indicating the inbreeding depression is repaired with the first generation of outcrossing. In general, the traits which deteriorate most with inbreeding respond most definitely to outcrossing. In many cases crosses of selected lines have given results superior to non-inbred stocks (Robison, cited by Craft, 1953; Chambers and Whatley, 1951; Dickerson *et al.*, 1946).

Because of the pronounced loss of vigor and productivity associated with inbreeding, inbred lines of swine are likely to have practical usefulness only if inbreds from lines selected for high combining ability can be kept in relatively small numbers and crossed to produce in large numbers non-inbred seed stocks which possess most of the superior transmitting ability exhibited by the parent lines. If the levels of transmitting ability tend to be a general characteristic of the lines, a small number of inbreds of each line could be used as basic seed stocks for multiplying crossline descendants that would in turn be used for commercial production. Conversely, if specific combining ability is the more important source of hereditary variation, the crosses between inbred lines are unlikely to retain much of the transmitting ability of the parent lines. Hence, larger numbers of inbreds will be required so the commercial stocks can be descended directly from the lines having the best specific combining abilities.

The aim of the present study was to measure the general and specific combining ability, and the general and specific maternal ability, in three-line crosses of 12 Poland China inbred lines. The characteristic studied was weight for age as measured at 154 days.

Materials and Methods

The data were from 2137 pigs produced by crossing 12 inbred lines of Poland China swine. The general plan was to produce single cross females

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and to mate these to males of a third line. Thus each litter had an inbred sire and a crossline mother, the mother in turn having an inbred sire and an inbred dam from a second and third line. A few of the dams were crosses of three or more lines. Only 43 of the 66 possible types of crossline dams were represented in the study, while 197 of the 660 possible three way crosses were present.

The pigs were produced on two farms where similar methods of management were used. Most of the pigs were raised in two-acre, brome-alfalfa pasture lots of about 60 pigs each. From some litters four representative pigs were fed as a group in small pens with concrete floors. All pigs were self-fed shelled corn and protein supplement from weaning to a market weight of about 200 lb. Because the number of litters in the different subclass groups was unequal, the method of least squares was used to estimate differences between the effects of the variables studied and to test the hypotheses statistically. This method was developed originally by Yates (1934), while the detailed statistical analyses used here were given by Henderson (1953).

A mathematical model involving the following constants was fitted to the data:

(1) A general mean or average which included the effects that were alike for all pigs and hence did not cause any of the observed variation.

(2) The general combining abilities of the parental lines. These represent the additively genetic differences attributable to line differentiation, one-half coming from the line of sire and one-fourth from each of the lines represented in the crossline dam.

(3) The general maternal effects which were common to all progeny that had a particular line as a grandparent. While these effects are environmental for the individual pigs, they are conditioned by the genes which cause the sows of a line to be particularly good or poor mothers.

(4) The specific maternal effects which resulted from the interaction of lines in producing particularly good or poor mothers, as distinct from the general maternal effects of the lines.

(5) The specific combining abilities which represent the extent that lines tend to contribute genes which enable their progeny from that particular cross to grow particularly well or poorly, as distinct from the general combining abilities of the lines.

(6) A season-place effect due to environmental differences in different years, seasons and locations.

(7) A season-place X cross interaction which would be real if certain crosses departed distinctly from their general performance pattern in particular seasons and locations.

(8) A litter effect peculiar to litter mates within a particular cross and in a particular season and location.

(9) An error term representing the variation among litter mates.

The dams within a particular season-place were of the same age;

hence, season-place effects also include differences due to age of dam. The effect of inbreeding *per se* was negligible since all dams and progeny were crosslines involving different lines.

Results and Discussion

The analysis of variance is shown in table 1. Each sum of squares was obtained by subtracting the reduction in sum of squares when that factor was ignored from the reduction in sum of squares when that particular factor was included along with all others. This procedure

TABLE 1. ANALYSIS OF VARIANCE FOR 154-DAY WEIGHTS

Sources of variation[a]	d.f.	Sum of squares	Mean square
Interaction between three-way crosses and season-place groups	228	347,574	1,524
Season-place groups	18	263,398	14,633**
General combining ability	11	57,877	5,262**
General maternal line effects	11	8,865	806
Specific combining ability	143	273,433	1,912
Specific maternal line effects	30	54,074	1,802
Litters within three-way cross season-place sub-classes	39	56,682	1,453**
Pigs within litters	1655	744,464	450

** $P<.01$.
[a] Adjusted for all other effects.

attributes to each source only the variation which is associated directly with that factor *after* the other factors in the model have accounted for all the variation possible; that is, by this method none of the joint effects are attributed to any factor.

The mean square for litter effect was highly significant when tested against the intralitter mean square. Hence, the 1453 for mean square between litters was used for all other tests of significance.

The single most important source of variation was season-place groups, as might be expected, since this source contains difference between farms, winter and summer growing conditions, and age of dam, as well as many other variables which were not uniformly controlled on the two farms and over the several seasons.

Differences in general combining ability of the lines are of particular interest. This source borders on high significance ($P=.02$), and was the most important genetic source of variation. However, its magnitude was small as compared with the total variation. This is shown by the component of variance analysis in table 2. The ratio, $G/[E+L+G]=27/[450+228+27]=.04$, indicates that pigs from the same three-way cross (but from different litters) will vary 4% less in their weights than unrelated pigs of the same season-farm group. The estimate of general combining

TABLE 2. MEAN SQUARES, EXPECTATIONS, AND ESTIMATES OF VARIANCE COMPONENTS

Sources of variation	d.f.	Mean square	Expectation of the mean square[a]
General combining ability	11	5,262	E+4.4L+143.6G
Litters within subclasses	39	1,453	E+4.4L
Pigs within litters	1655	450	E

[a] E=450; L=228; G=27.

ability is expected to contain one-half of the additively genetic variance which had accumulated among the lines during the inbreeding. Since the average inbreeding of the lines was 46%, an estimate of the additively genetic variance which presumably existed among the individual pigs of the foundation stocks is .04/.46=.09. The sampling error of this estimate must be quite large since it is based on only the twelve values for the lines. It is smaller than the estimates obtained in the initial stages of inbreeding but is larger than the estimate of 0.7 obtained from intra-line regression of offspring on parent by Cockerham (1952) from data taken on the inbred lines from 1938 to 1950.

General maternal effects of the lines were small relative to the sampling error (table 1). There was somewhat more evidence for the existence of specific combining ability and for specific maternal line effects but these also fell far short of the .05 probability level conventionally regarded as necessary for disproving the hypotheses that these sources are not real.

The estimates of the values for general combining ability and for general maternal effects for each of the 12 lines are given in table 3. While there is a negative correlation of —.38 between these values this is not

TABLE 3. NUMBER OF SIRES, PERCENT INBREEDING AND ESTIMATES OF COMBINING ABILITY AND MATERNAL EFFECTS BY LINES

Lines	No. of sires	Inbreeding in 1947	General combining ability	General maternal effect
A	2	40	2	5
B	2	37	—3	1
C	1	46	—6	—7
D	1	46	2	2
E	1	64	—2	—4
F	1	47	—2	5
G	1	48	12	—5
H	2	54	10	—5
I	1	60	—6	5
J	1	65	1	—3
K	1	53	—6	2
S	4	36	—2	4

unbiased evidence that a negative correlation exists between the gene complex which influences growth rate directly and the gene complex which affects maternal ability, as was suggested by Bradford *et al.* (1958) in a similar study. A negative correlation is induced automatically between estimates where one set of estimates must be calculated by subtracting from equations containing the other set. This is quite apart from the biology of the situation where the correlation may be zero, as was assumed in the model, or positive, if the genes which cause pigs to grow well also cause them to be better mothers. The best practical solution to obtaining an estimate of this correlation seems to be that of computing values from different sets of data, and this is done in a subsequent study.

Sires from five of the lines had been used in paired comparisons with boars of regular purebred breeding on 28 different farms. Weights were

TABLE 4. ESTIMATES OF GENERAL COMBINING ABILITY FROM THREE-LINE CROSSES AND FROM FARM TESTS

Line	Three-line crosses	Farm tests
A	2	4
B	−3	−5
C	−6	−10
G	12	12
S	−2	−1

taken on their pigs at 154 days of age and estimates of the line effects made from the differences between the progeny of the inbred and purebred boars on the same farms. The results summarized in table 4 indicate that there is a high degree of correspondence between the estimates obtained from the three-line crosses in the experimental herd and those obtained on farms. Since the progeny on farms were from crossberd sows of many different breeds, this correspondence indicates that the same genes contribute to rapid growth in the Poland line crosses and in the crossbreds.

The experiment was planned originally so the simultaneous effects of inbreeding and selection could be studied. This was accomplished primarily by having different numbers of sires for the lines, with about 10 females per sire. As shown in table 3, the one-sire lines had the highest average inbreeding; the two-sire lines were intermediate, and the only four-sire line was lowest in inbreeding. There is no apparent trend in the estimates of either general combining ability or in maternal effect with reference to level of inbreeding or number of sires used per line. This substantiates for three-line crosses the conclusion reached from the performance of inbreds (Dickerson *et al.*, 1954) and for the performance of single crosses (Henderson, 1949) that rate of inbreeding when the lines were being formed had no measurable effect upon final merit of the lines.

An estimate of how single crosses between these inbred lines are

expected to perform can be obtained from the estimates for general combining abilities and general maternal effects in table 3. For example, a good cross would be that of using a G sire on an A female, the estimate for the pigs being 12+2+5=19 lb. above average at 154 days of age. If a three-way cross were produced by mating an inbred sire with a cross-line female, the expected value of the progeny would be the sum of the general combining ability for the sire line plus one-half the sum of the two general combining abilities and the two general maternal effects for the two lines of breeding in the dam.

Summary

Differences in the general combining abilities and the general maternal effects were estimated from 2137 three-line cross pigs of 12 Poland China inbred lines. Differences in general combining ability were statistically significant, accounting for 4% of the variation among pigs of the same season-farm group. Maternal effects of the lines and the interactions involving specific effects were not statistically significant. There was good agreement between the direct transmitting abilities of the lines when estimated from the three-line cross data and when estimated for five of the lines in farm herds where they were used for commercial production.

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ALFALFA MEAL AS A SOURCE OF ENERGY BY SWINE [1]

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THE lack and relatively high price of concentrate feeds in California have stimulated interest in the possible use of more home-grown alfalfa. Further impetus was received from the first report of the Nevada Agricultural Experiment Station that one pound of alfalfa replaced nearly one pound of grain in rations containing as high as 50% alfalfa meal (McCormick and Kidwell, 1953). As the level of alfalfa meal was increased from 0 to 50%, rate of gain decreased but was still one pound per day or better with 50% alfalfa meal in the ration (McCormick and Kidwell, 1953; Bohman *et al.,* 1953, 1955; Kidwell and Hunter, 1956). Hogs receiving the higher levels of alfalfa meal consumed less feed daily and required more feed per unit of gain (Bohman *et al.,* 1955; Kidwell and Hunter, 1956). Replacement values per pound of alfalfa varied from 0.13 lb (Bohman *et al.,* 1955) to 0.51) lb. of concentrate (Kidwell and Hunter, 1956). For best results, good quality alfalfa was important (Kidwell and Hunter, 1956).

Decreased rate of gain due to feeding increased levels of alfalfa has been reported by many others including Crampton *et al.* (1954), Becker *et al.* (1956) and Merkel *et al.* (1958); increased fiber levels, by Alexsson and Eriksson (1953). Lowered daily feed consumption on high alfalfa rations has also been reported by Becker *et al.* (1956), whereas increased feed intake due to increased fiber content was reported by Axelsson and Eriksson (1953) and to increased alfalfa levels by Crampton *et al.* (1954) and Merkel *et al.* (1958). Increased feed per unit of gain on high alfalfa rations has also been reported by Crampton *et al.* (1954), Becker *et al.* (1956) and Merkel *et al.* (1958). Work by Hanson *et al.* (1956) indicated that most of the growth-depressing property of alfalfa meal is due to lowered TDN content of the ration and lowered feed consumption.

The importance of this field of investigation invites further work. The relative success with extremely high alfalfa levels in the Nevada work coupled with the reported differences in feed consumption response led to this study.

Experimental

The alfalfa (variety *Caliverde*) for these studies was the second cutting of a uniform second year stand. Stage of maturity was deter-

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[2] Department of Animal Husbandry.
[3] The authors would like to acknowledge the assistance of L. G. Jones of the Agronomy Department in the identification and selection of the various stages of maturity.

mined by a hand count of several hundred stems selected at random at time of harvest. Any stem with a bud or blossom was considered to be in the bud or bloom stage, and, for example, 3% bloom means that 3% of the stems actually counted had at least one blossom. The remainder of the stems would be less mature.

This study was conducted as a three-factor experiment (3x3x3) in randomized blocks. In addition to 3 levels of alfalfa meal (5, 20 and 40% of the ration), stage of maturity and method of preparation were studied. Three stages of maturity were included; 16% bud, 3% bloom, and 34% bloom.

TABLE 1. COMPOSITION OF RATIONS[a]

Ingredient	Ration no. 1	2	3
Alfalfa meal, lb.	5.0	20.0	40.0
Ground barley, lb.	73.75	58.75	38.75
Meat and bone scraps, lb. (50% protein)	7.5	7.5	7.5
Soybean meal, lb.	6.5	6.5	6.5
Cottonseed meal, lb.	6.5	6.5	6.5
NaCl, lb.	.5	.5	.5
Zinc sulfate, gm.	20.5	20.5	20.5
Irradiated yeast, gm.	1.0	1.0	1.0

[a] Antibiotic supplement was provided in replicates 1 and 2 by addition of ¼ lb. Aurofac 2A (3.6 gm. chlortetracycline HCL activity per lb.) and in replicate 3 by addition of 41 gm. Terramycin supplement TM-5 (5 gm. oxytetracycline HCl activity per lb.).

All alfalfa was fed as a medium ground meal; the three methods of preparation were suncured, dehydrated and pelleted dehydrated, reground.

Pigs where housed in groups of five or six in an experimental barn. Twice daily they were placed in individual feeding stalls with free access to feed for a period of at least 90 minutes. Water was available *ad libitum*. The composition of the ration is shown in table 1. Ration 1 is adequate (Beeson *et al.*, 1953), and the alfalfa substitution for barley in rations 2 and 3 tests alfalfa as a source of energy. The crude protein, lignin, and holocellulose contents of the various meals are given in table 2.

Three replicates each with 27 pigs were run. The pigs in replicates 1 and 3 were purebred Duroc barrows and gilts from the University herd. Those in replicate 2 were purchased crossbred Chester White x Yorkshire barrows and gilts. The average initial weights and experimental periods of the three replicates were 60, 70, and 75 lb. and 63, 49, and 63 days, respectively. At the end of each replicate backfat thickness was determined with the Lean Meter at the three conventional sites.

TABLE 2. ANALYSES OF ALFALFA HAYS [a]

Method of preparation	Stage of maturity	Crude [b] protein, %	Lignin [c] %	Holocellulose [d] %
Suncured	16% bud	24.1	6.4	39.5
	3% bloom	23.9	7.1	38.7
	34% bloom	19.8	8.4	40.6
	Mean	22.6	7.3	39.6
Dehydrated	16% bud	26.0	5.9	40.3
	3% bloom	26.7	6.0	36.0
	34% bloom	21.6	7.3	40.9
	Mean	24.8	6.4	39.1
Pelleted dehydrated, reground	16% bud	25.1	6.1	
	3% bloom	25.1	6.8	
	34% bloom	20.5	7.6	
	Mean	23.6	6.8	
Mean of above	16% bud	25.1	6.1	
	3% bloom	25.2	6.6	
	34% bloom	20.6	7.8	
	Mean	23.6	6.8	
Field samples [e]	16% bud	27.1	5.6	41.8
	3% bloom	26.4	7.0	40.3
	34% bloom	22.0	8.0	45.9
	Mean	25.2	6.9	42.7

[a] Dry matter basis.
[b] Method, A.O.A.C. (1955).
[c] Method, Ellis *et al.* (1946) modified by autoclaving of samples, as suggested by Thacker (1954), rather than boiling.
[d] Method, Wise *et al.* (1946).
[e] Sample taken at time of harvest of each stage of maturity.

Results and Discussion

The results for average daily gain, average daily feed consumption, and final backfat thickness are given in tables 3, 4, and 5, respectively. Analysis of covariance was made on daily gain and feed consumption.[4] Daily gains adjusted by partial regression to equal feed consumption (5.25 lb. per day) are also shown in table 3.

Differences in actual daily gain and daily feed consumption due to level of alfalfa meal were highly significant (tables 3, 4). When daily gains were adjusted for differences in feed consumption (adjusted to feed consumption 5.25 lb. per day), the differences were less in magnitude, yet still highly significant (table 3). The actual daily gains in the trials reported herein were reduced with increases in alfalfa meal content of the ration about the same in magnitude as in the studies of Bohman *et al.* (1955) and Becker *et al.* (1956). This reduction was proportionally

[4] Mean squares for level = 0.31655**, for stage of maturity = 0.0060, and for method of preparation = 0.07365**. Interactions not significant.

greater than that reported by McCormick and Kidwell (1953), Bohman *et al.* (1953) and Kidwell and Hunter (1956). Daily gain and feed consumption were not affected by stage of maturity under the conditions of this experiment. Daily gain was lower on the rations including suncured hay than on those containing hays prepared by the other two methods even though feed consumption remained unaffected by method of preparation.

Since daily gains of pigs receiving different levels of alfalfa meal differed significantly when corrected to equal feed consumption (table 3), it follows that gain per unit of feed was reduced as more alfalfa meal was

TABLE 3. AVERAGE DAILY GAIN OF PIGS FED ALFALFA [a]

Level fed	Method of preparation [b]	Av. daily gains when alfalfa at—		
		16% bud stage	3% bloom stage	34% bloom stage
%		lb.	lb.	lb.
5	S	1.41	1.52	1.51
	D	1.60	1.53	1.58
	P	1.51	1.67	1.59
20	S	1.23	1.15	1.28
	D	1.33	1.22	1.32
	P	1.44	1.35	1.30
40	S	0.80	0.90	0.92
	D	0.88	0.85	0.87 [c]
	P	0.98	0.86	0.91

Items	Summated means	
	Actual	Adjusted [d]
Level		
5%	1.55	1.42
20%	1.29 [e]	1.25 [e]
40%	0.88 [e]	1.05 [e]
Stage		
16% bud	1.24	1.23
3% bloom	1.23	1.24
34% bloom	1.25	1.25
Preparation [b]		
S	1.19 [f]	1.17 [g]
D	1.24	1.26
P	1.29	1.29

[a] Averages for 3 animals, one for each replicate.
[b] S=suncured, D=dehydrated, P=pelleted dehydrated, reground.
[c] Animal missing first replicate. Missing value calculated.
[d] Adjustment by partial regression as explained in text.
[e] Difference from other levels highly significant ($P<0.01$).
[f] Difference from pelleted dehydrated, reground, meal significant ($P<0.05$) and from dehydrated meal approaching significance.
[g] Difference from other methods of preparation highly significant ($P<0.01$).

placed in the ration. Similarly, gain per unit of feed was less on rations containing suncured alfalfa meal than on those containing other meals.

Backfat thickness was greater in pigs fed 5% alfalfa meal (table 5) as would be expected because the pigs weighed more. The difference in backfat thickness between the pigs fed 20% and 40% alfalfa meal approached statistical significance.

At the end of each replicate TDN was determined with lignin as a reference substance in combination with the method of Lofgreen (1953). The results are summarized in table 6 and indicate that TDN was affected by level of alfalfa as would be expected. Stage of maturity and method of preparation had no effect. Since alfalfa was added at the two higher levels at the expense of barley, the relative TDN of barley and

TABLE 4. AVERAGE DAILY FEED CONSUMPTION [a]

Level fed	Method of preparation [b]	Av. daily feed when alfalfa at—		
		16% bud stage	3% bloom stage	34% bloom stage
%		lb.	lb.	lb.
5	S	6.28	6.53	6.60
	D	6.88	6.03	6.36
	P	6.12	6.40	6.06
20	S	5.35	5.43	5.60
	D	6.03	4.93	5.56
	P	6.13	5.51	5.80
40	S	4.11	4.18	4.37
	D	4.06	2.52	3.93 [c]
	P	3.68	3.71	3.64

Items	Summated means
	Actual
Level	
5%	6.36
20%	5.59 [d]
40%	3.80 [d]
Stage	
16% bud	5.40
3% bloom	5.03
34% bloom	5.32
Preparation [b]	
S	5.38
D	5.15
P	5.23

[a] Averages for 3 animals, one for each replicate.
[b] S=suncured, D=dehydrated, P=pelleted dehydrated, reground.
[c] Animal missing first replicate. Missing value calculated.
[d] Difference from other levels highly significant ($P<0.01$).

TABLE 5. BACKFAT THICKNESS [a, b]

Level fed	Method of preparation [c]	Backfat thickness when alfalfa at— 16% bud stage	3% bloom stage	34% bloom stage
%		in.	in.	in.
5	S	1.2	1.2	1.2
	D	1.1	1.1	1.1
	P	1.4	1.3	1.0
20	S	1.0	0.8	0.9
	D	1.0	1.0	0.9
	P	1.0	0.9	0.9
40	S	0.9	0.8	0.8
	D	0.8	0.6	0.7 [d]
	P	0.8	0.8	0.7

Items	Summated means Actual
Level	
5%	1.2 [e]
20%	0.9
40%	0.8
Stage	
16% bud	1.0
3% bloom	0.9
34% bloom	0.9
Preparation [c]	
S	1.0
D	0.9
P	1.0

[a] Determined by Lean Meter in 3 standard locations.
[b] Averages for 3 animals, one for each replicate.
[c] S=suncured, D=dehydrated, P=pelleted dehydrated, reground.
[d] Animal missing first replicate. Missing value calculated.
[e] Difference from other levels highly significant ($P<0.01$).

alfalfa can be estimated by difference under the conditions of this experiment. In this experiment the average TDN of all alfalfa meals was 34 lb. less per 100 lb. than barley. This would be expected owing to the low utilization of holocellulose by simple stomached animals (Meyer, 1954).

The replacement value of alfafa meal as used in this experiment was calculated from average daily gain figures adjusted to an average daily feed consumption of 5.25 lb. by partial regression. Adjusted data were used because it reduces variation due to differences in feed consumption and presumably would reduce differences due to composition of gain (table 5). Using feed utilization comparisons between the 5 and 20%, 5 and 40%, and 20 and 40% alfalfa meal levels, the replacement values were 0.24, 0.28, and 0.31 lb. of concentrate per pound of alfalfa meal,

TABLE 6. TOTAL DIGESTIBLE NUTRIENTS OF VARIOUS RATIONS [a, b]

Level fed	Method of preparation [c]	TDN when alfalfa at—		
		16% bud stage	3% bloom stage	34% bloom stage
%		%	%	%
5	S	70	76	73
	D	71	75	73
	P	75	76	75
20	S	65	69	70
	D	71	65	66
	P	68	66	67
40	S	59	63	60
	D	71	61	60
	P	61	61	60

Items	Summated means
	Actual
Level	
5%	74
20%	67 [d]
40%	62 [d]
Stage	
16% bud	68
3% bloom	68
34% bloom	68
Preparation [c]	
S	67
D	68
P	68

[a] Averages for 3 animals, one for each replicate.
[b] Dry matter basis, %.
[c] S=suncured, D=dehydrated, P=pelleted dehydrated, reground.
[d] Difference from other levels highly significant ($P<0.01$). F value for level = 36.02.

respectively, the average of these being 0.28 lb. This low replacement value is considerably less than would be predicted from commonly accepted TDN or net energy values of the ration ingredients and the alfalfa meal (Schneider, 1947; Morrison, 1956).

Poor performance and a low TDN generally would be expected on a high roughage ration for swine. No reason can be advanced for the relatively good performance in some experiments. Quality of hay probably is important (Kidwell and Hunter, 1956) even though the quality of alfalfa used in these trials appeared excellent (table 2). Quality of hay as indicated by stage of maturity and method of preparation under the conditions of this experiment was of little or no effect. It has been suggested (McCormick and Kidwell, 1953) that breed and selection may play a part in utilization of higher levels of alfalfa meal.

Summary

The value of alfalfa meal as a source of energy for swine was determined for three levels of meal (5, 20, and 40%), three stages of maturity (16% bud, 3% bloom and 34% bloom) and three methods of preparation (suncured, dehydrated and pelleted dehydrated, reground). All hays were specially prepared from the second cutting of a uniform field. Three replicates were run of a three-way factorial experiment, one pig being used per treatment per replicate. Pigs were individually fed.

Rate of gain, feed consumption and gain per unit of feed consumed were reduced by increased levels of alfalfa meal ($P<0.01$). Rate of gain was less on rations containing suncured meal in comparison to the other methods of preparation. Stage of maturity was without effect under the conditions of this experiment.

Poor utilization of alfalfa as a source of energy is indicated by a TDN content of the hays in this experiment averaging 34 lb. less per 100 lb. than barley. Using gains adjusted to equal feed consumption, it was calculated that the average replacement value of one pound of the alfalfa meal used in these experiments was 0.28 lb. of concentrate.

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PELLETED RATIONS COMPARED TO SIMILAR RATIONS FED CHOPPED OR GROUND FOR STEERS AND LAMBS

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PELLETING of hay and other feeds for ruminants is developing rapidly as a new method of preparation for livestock feed. Increased gain and improved feed efficiency resulting from pelleting feeds for lambs have been reported by several authors (Cate *et al.*, 1955; Lindahl and Davis, 1955; Neale, 1955). Esplin *et al.* (1957) have reviewed the results reported by nine experiment stations on feeding pellets to lambs. These authors concluded that improved performance on pellets was due largely to increased feed consumption; when equal amounts of pellets or meal were fed differences in performance were not obtained. Jones *et al.* (1958) have reported on feeding alfalfa as pellets, wafers (large pellets of chopped hay) and long hay to dairy cows which were also receiving a concentrate mixture. Many reports on feeding pelleted rations to beef cattle have appeared in the popular press, feeders' day reports and abstracts.

The effect of pelleting on digestibility of a ration is somewhat controversial. Blaxter and Graham (1956) reported a depressed digestibility on pelleted roughage, but several other workers have reported only negligible or no effect (Long *et al.*, 1955; Lindahl and Davis, 1955; Meyer *et al.*, 1958; Esplin *et al.*, 1957).

Three trials with cattle and sheep are reported in this paper comparing pelleted rations to chopped or meal rations.

Procedure

Sheep Study

The effect of pelleting high roughage rations for fattening lambs was studied by a feeding trial and a digestion trial.

Feeding Trial. Forty commercial feeder lambs were allotted at random into four lots of ten lambs each. All of the alfalfa used for the various rations was taken from the same field at the same time. The alfalfa grown at the Imperial Valley Field Station, El Centro, California, was cut on October 30, 1955, at the 10% bloom stage. The alfalfa averaged 23 in. in height, contained 42% leaves and as cut had a dry matter content of 20.4%. Immediately after cutting, it was taken to a commercial dehydrator for drying. The portion to be fed as chopped hay was taken directly from the dehydrator and sacked. The hay to be pelleted was ground immediately through a 1/16-in. screen and pelleted into

⅜-in. pellets. All of the barley used was from one lot of barley grown at the Field Station. The composition of the rations is shown in table 1, the values being averages of a minimum of three samples collected during the course of the digestion trials at Davis. The slightly lower protein values and higher crude fiber values for the rations containing the chopped hay are attributed to greater leaf loss in handling and/or to sampling error.

The lambs were hand-fed twice daily in drylot all of the feed they would eat. The lambs fed chopped hay plus barley were started on the

TABLE 1. COMPOSITION OF FEEDS [a]

Feed	Protein, %	Ash, %	Ether extract, %	Crude fiber, %	Lignin, %
Alfalfa before harvest	20.3	11.7	—	28.5	7.9
Chopped dehydrated alfalfa hay	18.4	11.5	2.0	29.3	9.2
Pelleted dehydrated alfalfa hay	21.0	12.4	2.3	25.3	9.0
Chopped dehydrated alfalfa hay plus 30% ground barley	15.1	8.9	1.7	23.8	7.5
Pelleted dehydrated alfalfa hay with 30% ground barley	16.9	8.5	2.2	20.6	6.2

[a] Dry matter basis.

barley slowly so that their barley intake over the entire feeding period averaged only 24% of the ration. The two groups fed the 30% barley pellets were started on straight alfalfa pellets for the first few days with the result that the intake for these two lots averaged 28% barley for the entire feeding period. All weights were obtained after 12 hours off feed and water. All lambs were fed for 84 days. At the end of the feeding period the lambs were shipped to the Los Angeles area for slaughter where individual shrinkage and carcass grades were obtained.

Digestion Trial. The feeds used in the feeding trial were shipped to Davis for a 6x6 Latin-square digestion trial conducted with yearling wethers. Seven-day preliminary periods and seven-day collection periods were used. All rations were fed at a level calculated to give approximately 110% of maintenance on the all-roughage rations. Laboratory analyses were made according to A.O.A.C. methods (1950). Statistical analyses were according to Snedecor (1946). Total digestible nutrients were calculated according to the organic matter method of Lofgreen (1953).

Steer Study I

Pelleted and long alfalfa hay were compared as feed for fattening steers.

All hay came from the same field at the Imperial Valley Field Station.

The hay was baled and then divided equally between that to be fed long and that to be pelleted. The portion for pellets was ground through a 3/64-in. screen and then made into pellets 13/64 in. in diameter. The baled hay fed long analyzed 20.7% protein and 8% lignin. After pelleting the analysis was approximately the same, 21.0% protein and 7.7% lignin.

During the winter of 1956–57, two lots of three steers each were fed free choice each of the forms of alfalfa hay. In addition, each steer received 2 lb. of barley and 2 lb. of long oat hay daily. The animals were fed for 167 days. Weights were taken after an overnight stand without

TABLE 2. COMPOSITION[a] OF RATIONS FED IN STEER STUDY II

Ration		Protein, %	Lignin, %
Meal			
Alfalfa	100%	17.3	7.7
Alfalfa Concentrates[b]	70% 30%	16.2	6.0
Alfalfa Concentrates[b]	40% 60%	14.6	3.6
Pellets			
Alfalfa	100%	18.0	8.1
Alfalfa Concentrates[b]	70% 30%	17.4	5.7
Alfalfa Concentrates[b]	40% 60%	15.9	3.9
Oat hay		9.2	6.2

[a] Dry matter basis.
[b] Concentrates consisted of 3 parts ground barley and 1 part molasses dried beet pulp.

feed or water. At the close of the feeding period, dressing percent, carcass grade and carcass fat (as estimated from analysis of the 9th, 10th and 11th rib) were obtained on each animal.

Steer Study II

Pelleted and meal rations containing zero, 30 and 60% concentrates were compared as feed for fattening steers.

All hay used in this study was grown and baled at the Imperial Valley Field Station and divided equally between that to be fed as meal and as pellets. The concentrate portion of the rations consisted of 75% barley and 25% molasses dried beet pulp. The protein and lignin content of the rations as fed is shown in table 2. The pellets were prepared by grinding the hay and barley and then after mixing, ¼-inch pellets were prepared. The milled ration was mixed from the ground barley (⅜-in. screen), beet pulp and hay which had been ground through a ¾-in. or

1-in. screen in the hammer mill. A limited amount of long oat hay was fed to all lots. The mean long hay daily consumption per steer was 0.52 lb. of dry matter and is included in all feed consumption figures.

Fifty-four grade Hereford, yearling steers were assigned at random to 18 lots of three steers each. Each of the six rations was fed to three pens of steers. The steers were on feed 152 days during the winter of 1957–58. All weights were obtained after an overnight stand without feed and water. At the close of the feeding period all steers were slaughtered and carcass data obtained. Body fat was determined from carcass specific gravity (Kraybill, *et al.*, 1951).

Results

Sheep Study

Feeding Trial. The results of the feeding trial are shown in table 3. The gains of the lambs fed the pelleted rations are significantly higher ($P<.01$) than those obtained on the unpelleted rations. The addition of barley did not significantly increase the gains.

Feed consumption in each case was increased by pelleting the ration compared to the similar unpelleted ration. The addition of the barley decreased the feed intake per lamb as compared to the all roughage ration. Efficiency of feed utilization was increased by pelleting as well as by the addition of barley to the ration.

The dressing percentage was higher for the lambs fed the pelleted hay ration ($P<.01$) than for the lot fed chopped hay. With the rations containing barley, the pellets with barley produced lambs with a higher dressing percentage than those fed the same ration as chopped hay and barley. The pellet-fed lambs also graded higher with 19 out of 20 in the

TABLE 3. RESULTS OF LAMB FEEDING TEST [a]

Items	Chopped alfalfa	Pelleted alfalfa	Chopped alfalfa plus barley	Pelleted alfalfa plus barley
Average initial weight, lb.	66.5	66.9	66.7	66.6
Average daily gain, lb.	0.30 [b]	0.39	0.31 [b]	0.36
Average daily feed, lb.	3.1	3.7	2.8	3.2
Feed per 100 lb. gain, lb.	1031	943	916	897
Dressing, %	49.8 [c]	53.1	52.4 [d]	55.2
Carcass grades:				
Choice	3	9	8	10
Good	7	–	2	—
Utility	–	1	–	—

[a] Ten lambs per lot.
[b] Highly significant smaller than that of other lots.
[c] Significantly lower ($P<.05$) than chopped hay and barley; highly significantly lower ($P<.01$) than that for lots fed pellets.
[d] Highly significantly lower ($P<.01$) than that of lot fed pelleted alfalfa and barley.

TABLE 4. RESULTS OF DIGESTION TRIAL WITH LAMBS [a]

Ration	Digestion coefficients		Total digestible nutrients
	Crude protein	Crude fiber	
			%
Chopped alfalfa hay	69	51 [a, b]	56 [f]
Pelleted alfalfa hay	69	47 [b, c]	55 [f]
Chopped alfalfa hay with 30% ground barley	69	53 [a]	65 [e]
Pelleted alfalfa hay with 30% ground barley	70	42 [d]	65 [e]

[a] Values with different superscript letter are significantly different. Value with the same superscript letter or that letter in combination with another letter are not significantly different; a>b>c>d ($P<.05$) and e>f ($P<.01$).

choice grade as compared to 11 out of 20 choice in the lambs fed chopped hay rations.

Digestion Trial. The results of the digestion trial are shown in table 4. The apparent digestibility of the protein fraction was quite uniform. Barley caused a decrease in crude fiber digestibility in the pellets only. Pelleting of both rations lowered the digestion coefficients for crude fiber but had no influence on the total digestible nutrient content.

Steer Study I

When steers were fed a limited amount of barley and oat hay plus alfalfa hay or alfalfa pellets free choice, the daily feed intake and the average daily gain were markedly higher for the steers fed the pelleted alfalfa (table 5). Feed efficiency was also slightly in favor of the pellet-fed animals.

TABLE 5. TWO LOTS OF SIX HEREFORD STEERS EACH FED THE SAME ALFALFA HAY IN TWO FORMS, LONG AND PELLETS, FOR 167 DAYS

Items	Alfalfa hay	Alfalfa pellets
Av. initial weight, lb.	636	640
Av. daily gain, lb.	1.80	2.17 [a]
Av. daily feed, [b] lb.		
Barley	1.81	1.81
Alfalfa hay	14.02	—
Alfalfa pellets	—	17.08
Oat hay	1.76	1.59
Total	17.59	20.48
Feed/100 lb. gain	980	945
Dressing percent	58.7	59.8
Carcass fat, %	26.4	25.7
Grade	5 Choice 1 Good	6 Choice

[a] Significantly ($P<.05$) higher than average daily gain of hay-fed steers.
[b] All feed is on a dry basis.

The carcass data indicate that all animals had reached satisfactory market condition on a minimum of grain.

Steer Study II

The gain and feed consumption data are reported in table 6. In analyzing the gain data, significant interactions were encountered between ration preparation and concentrate level. Analysis of variance within ration preparation revealed no significant difference in gain by concentrate levels

TABLE 6. GAIN AND FEED INTAKE DATA ON STEERS FED PELLETED OR MEAL RATIONS WITH VARIOUS CONCENTRATE-ROUGHAGE RATIOS

Items	Pellets			Meal		
	Alfalfa 100%	Alfalfa 70% Concentrates 30%	Alfalfa 40% Concentrates 60%	Alfalfa 100%	Alfalfa 70% Concentrates 30%	Alfalfa 40% Concentrates 60%
Average daily gain, lb.	2.22[b]	2.29	2.14[c]	1.75[a, b]	2.07[a]	2.46[a, c]
Adjusted* daily gain, lb.	1.87[d]	2.18[d]	2.59[d]	1.81[d]	2.03[d]	2.43[d]
Daily feed consumption (dry basis), lb.	22.4[e, f]	20.6[e]	16.3[e, g]	19.3[f]	20.0	20.0[g]
Feed per cwt. gain (dry basis), lb.	1010	918	768	1103	967	809

[a] Highly significant ($P<.01$) difference in gain on milled ration at various concentrate levels.
[b] Gains highly significantly ($P<.01$) higher on pellet than on meal ration with no concentrates.
[c] Gains significantly higher ($P<.05$) on meal than on pellet ration with 60% concentrates.
[d] Highly significant ($P<.01$) difference in adjusted daily gains by concentrate level.
[e] Highly significant ($P<.01$) difference in dry matter intake between various concentrate levels fed as pellets.
[f] Dry matter intake significantly ($P<.05$) lower on meal ration than on pellet ration with no concentrates.
[g] Dry matter intake significantly ($P<.05$) lower on pellet ration than on meal ration with 60% concentrates.
* Adjusted to equal dry matter intake by covariance technique.

for pellets but a highly significant difference between concentrate levels with the milled rations. When the gains between pellets and milled rations at the various concentrate levels were tested by the "t" test, the gains were highly significantly ($P<.01$) larger on pellets with no concentrate added, not different at the 30% concentrate level and significantly ($P<.05$) lower on pellets with 60% concentrates. When the average daily gains were adjusted to an equal dry matter intake by the covariance technique, a highly significant difference ($P<.01$) was found between concentrate level with both types of feed preparation.

Analysis of feed consumption (by lots of three steers) also revealed significant interactions between feed preparation and concentrate level. Analysis within feed preparation showed no significant effect on feed consumption by concentrate level for the meal ration but a highly significant effect ($P<.01$) of concentrate level on feed consumption for pellets. Tests between feed preparation within concentrate levels revealed that the feed intake was significantly ($P<.05$) lower on the meal ration than on the

pellet ration when no concentrates were added; there was no difference when 30% concentrates were added, and a significantly ($P<.05$) lower feed intake on pellets at the 60% concentrate level.

The carcass data is shown in table 7. The dressing percentage was highly significantly lower ($P<.01$) on the rations containing no concentrates for both the pellet and meal rations.

Analysis of the percent body fat again gave a significant interaction between feed preparation and level of concentrates. Within the pelleted rations, concentrate level did not show significant differences on fat con-

TABLE 7. CARCASS DATA ON STEERS FED PELLETED OR MEAL RATIONS WITH VARIOUS CONCENTRATE-ROUGHAGE RATIOS

Items	Pellets			Meal		
	Alfalfa 100%	Alfalfa 70% Concentrates 30%	Alfalfa 40% Concentrates 60%	Alfalfa 100%	Alfalfa 70% Concentrates 30%	Alfalfa 40% Concentrates 60%
Dressing percentage	57.3[a]	59.6	60.5	56.5[a]	59.5	59.5
Fat content of carcass, %	20.3[c]	22.8	22.9[d]	18.0[b, c]	22.1[b]	26.3[b, d]
U.S.D.A. carcass grades	9 Choice	1 Prime 8 Choice	7 Choice 2 Good	3 Choice 6 Good	8 Choice 1 Good	9 Choice

[a] Dressing % highly significantly ($P<.01$) lower on rations with no concentrates.

[b] Highly significant ($P<.01$) difference between fat content of steers on meal rations of varying concentrate levels.

[c] Fat content significantly ($P<.05$) higher in carcasses from steers fed pellets with no cencentrates than from those fed meal with no concentrates.

[d] Fat content significantly ($P<.05$) higher in carcasses from steers fed meal with 60% concentrates than from those fed pellets with 60% concentrates.

tent, but within meal rations level of concentrate did have a highly significant ($P<.01$) effect on body fat content. Within concentrate levels, the fat content was significantly higher for the steers fed pellets at the zero concentrate level, no difference at the 30% concentrate level, and significantly higher fat content for the steers fed the meal with 60% concentrates. The Federal carcass grades indicate that all of the lots except those fed the straight hay as meal were in acceptable market condition at the end of the experiment. The only steers fed the pellets which did not make the choice grade were two on the high concentrate pellet.

Discussion

The advantages of feeding high roughage rations as pellets to both sheep and steers have been confirmed in these feeding trials. Pelleted high quality alfalfa without the addition of concentrates produced excellent gains, good feed conversion and satisfactory carcasses with both lambs and steers. When chopped or ground hay was fed to lambs and to steers, feed consumption and gains were lower and both the lambs and steers failed to reach a satisfactory slaughter grade.

The incorporation of 30% concentrates in pelleted rations did not significantly increase the gains of either the lambs or steers and in both cases the daily feed intake was decreased compared to that on all roughage pellets. The feed efficiency, however, was increased for both species by the addition of the concentrates. At the 30% concentrate level the lambs gained more, ate more and had a higher dressing percentage when pellets were compared to chopped hay and barley. The differences between the performance of the steers on pellets or meal at the 30% concentrate level were non-significant. In the first cattle feeding study where a constant level of barley was fed separately and constituted only about 10% of the average daily feed, the steers fed hay pellets ate more and gained more than those fed the long hay.

The response of the steers to a pelleted ration containing 60% concentrates was very different from that to pelleted ration of lower concentrate levels. Compared to a similar ration fed in milled form the steers on pellets ate less and gained less. The carcasses contained less fat and did not grade as well as those fed on the meal ration. The steers fed the high concentrate pellets were more efficient in feed conversion, but this should be expected as they were not producing as much body fat as the meal-fed steers. Earlier Neale (1955) reported poorer performance of lambs fed pellets with 50% concentrates compared to lower concentrate pellets.

The explanation of the difference in response of ruminants to high concentrate rations in meal as compared to pellet form probably involves the difference in rate of consumption. The pelleted feed is consumed more rapidly and passes through the digestive tract more quickly (Meyer *et al.*, 1958; Blaxter and Graham, 1956). Reid *et al.*, (1957) have shown that lactic acid accumulation and lower rumen pH values are observed more often with high concentrate rations. These authors also suggest that an accumulation of lactic acid in the rumen tends to lower the appetite. An accumulation of lactic acid and a lowered rumen pH might account for the lowered feed consumption found when high concentrate rations are fed to ruminants in a pelleted form.

Increased gas production may also play a part in depressing the appetite on the high concentrate pellet. Meyer *et al.* (1958) have reported a more rapid gas formation of finely ground pellets compared to a similar chopped ration. This increased gas formation plus that which normally occurs in the rumen after the consumption of high concentrate ration may result in an appetite depression. A complete explanation of the basic cause of this appetite depression must await a more thorough understanding of metabolism within the rumen.

The digestibility of the protein in the lamb digestion trial was unaffected by the treatments. This is in agreement with the studies of Long *et al.* (1955) and Lindahl and Davis (1955) who found little, if any, difference between the digestibility of protein in pelleted and unpelleted feeds. Blaxter and Graham (1956), on the other hand, report a lower digestion

coefficient for protein in pelleted dried grass, particularly on higher intakes of feed. These authors studied two levels of intake of 600 gm. per 24 hours and 1500 gm. per 24 hours. The intake in the studies reported in this paper were about midway between the levels of Blaxter and Graham (1956) in that the intake per 24 hours was from 900 to 1000 gm.

Pelleting did depress the crude fiber digestibility particularly when barley was added to the ration. The magnitude of this depression is somewhat larger than that reported by Long *et al.* (1955) and Lindhal and Davis (1955), but smaller than the depression reported by Blaxter and Graham (1956), particularly on their higher level of intake.

The pelleting did not affect the total digestible nutrient content of the feeds. This finding is in agreement with the report of Lindahl and Davis (1955) who reported a small increase in total digestible nutrients as a result of pelleting. Although Long *et al.* (1955) do not report total digestible nutrients as such, inspection of their digestion coefficients indicates little, if any, change in total digestible nutrients. Blaxter and Graham (1956) report that in their studies finely ground and pelleted grass only furnished 85.5% as much total digestible nutrients as did the same material in chopped form, but on a net energy basis the pelleted material furnished 102.2 % of the chopped feed.

Summary

Similar rations were fed as pellets and as meal, chopped or long hay to both lambs and steers to compare pellets to more conventional methods of feed preparation. Pelleting was particularly advantageous for both steers and lambs when straight roughage rations were compared. Gains and feed intake were increased. Steers fed a constant feed of 2 lb. of barley consumed more feed and made larger gains when fed pellets compared to long hay. The addition of 30% concentrates to the pelleted rations did not significantly increase the gains of either lambs or steers, but did increase feed efficiency. At the 30% concentrate level the pellet-fed lambs performed better than lambs fed chopped hay and barley; however, with the steers the differences in performance between meal and pellets at this concentrate level were non-significant. Steers fed 60% concentrate pellets consumed less feed, and gained less and their carcasses contained less fat than steers fed the same ration in meal form. The pellet-fed steers were more efficient in converting their feed to gain. Possible reasons for the differing effect of pelleting at various concentrate levels are discussed.

A lamb digestion trial was used to study the alfalfa in chopped and pelleted form with and without added barley. Protein digestibility showed little difference. Fiber digestibility was lower for the pelleted rations compared to the chopped rations, particularly when barley was included in the ration. Pelleting did not affect the total digestible nutrient content of the lamb rations.

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ULTRASONIC MEASUREMENT OF FATNESS IN SWINE [1, 2]

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ACCURATE methods for measuring fatness in live animals are needed in studying tissue changes during growth and fattening and for measuring fatness at market weights of animals that cannot be killed for detailed carcass examinations. The mechanical probe (ruler) developed by Hazel and Kline (1952) and the electrical probe (Lean-Meter) of Andrews and Whatley have been sufficiently accurate for measuring fatness in swine at market weights. However, neither method is very satisfactory for young pigs that have less than 1.0 inch of backfat (Douce, 1954; DePape and Whatley, 1956), and neither method is accurate enough to recommend for use on beef cattle (Temple, 1956; Smith, 1957). Temple (1956) applied ultrasonic reflectance techniques to the problem of measuring fatness in beef cattle and suggested that this approach appeared promising. The present study was conducted to investigate the accuracy of ultrasonic measurement of fatness in swine.

Experimental

Fifty-six pigs of five breeds (Duroc, Hampshire, Landrace, Poland and Yorkshire) and one cross bred group were used as experimental animals. They varied in weight from 190 to 250 lb., and in age from 5 to 7 months. They had been grown on a high-energy ration of ground corn and protein supplement on brome-alfalfa pasture. There were 30 barrows and 26 gilts. Some of the gilts had been rejected as candidates for the breeding herd because of overfatness.

The pigs were prepared for ultrasonic measurement by clipping the hair over the back from the rump to the shoulder. A commercial 30-weight motor oil was applied to the surface of the skin and to the transmitting-receiving probe to assure a quick and adequate bond between the surface of the skin and that of the probe. The ultrasonic instrument used was the Kelvin and Hughes Mark V flaw detector. The operator had had only a minimum of training and experience with this instrument at the time the measurements were taken on the pigs. The pigs were driven singly into a crate that was open at the top to permit movement by the

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[2] The carcass data presented herein were obtained through the cooperation of Geo. A. Hormel and Co., Fort Dodge, Iowa.

operator. They were not restrained in any other way. Two difficulties were encountered in making correct readings with the flaw detector. First, even slight movements on the part of the pig cause fat depth and oscilloscope readings to vary. Second, the fascia is usually indicated clearly on the oscilloscope and some care is necessary in reading the oscilloscope to avoid mistaking this for the surface of the muscle.

Measurements of fatness were taken with both the ruler probe and the ultrasonic method at three standard sites: One of these was immediately behind the shoulder; one was at the middle of the back, and one

TABLE 1. MEANS AND STANDARD DEVIATIONS BY SEXES

Variable	Average		Standard deviation within sexes
	Gilts	Barrows	
Carcass weight, lb.	149.5	137.4	13.00
Lean cuts, %	52.3	52.0	2.87
Ham, %	19.9	19.4	1.19
Carcass backfat, in. (av. of 3 sites)	1.5	1.5	0.25
Mechanical probe			
Shoulder, in.	1.8	1.8	0.32
Back, in.	1.3	1.2	0.26
Loin, in.	1.3	1.3	0.23
Average	1.5	1.4	0.28
Ultrasonic probe (2.5 mc/s)			
Shoulder	6.1	7.0	1.49
Back	3.7	3.4	1.09
Loin	4.5	4.9	1.26
Average	4.9	5.1	1.18
Ultrasonic probe (1.5 mc/s)			
Shoulder	5.4	5.9	1.41
Back	3.7	3.2	0.91
Loin	4.5	4.3	1.14
Average	4.5	4.4	1.05

was at the rear of the loin. The measurements reported in detail here were taken about two inches off the midline of the body immediately over the longissimus dorsi. Anatomically these sites are at about the 6th rib, the 12th rib, and the last lumbar vertebra. Measurements were taken at ultrasonic frequencies of 1.5 mc/s and 2.5 mc/s. In order to assure complete independence of the two frequencies, all of the pigs were measured at one frequency and then mixed again and driven through the crate individually a second time for measurement at the other frequency.

After the ultrasonic measurements were completed the pigs were again mixed and were then measured by a different experienced operator with the ruler probe described by Hazel and Kline (1952). Immediately after measuring, the pigs were trucked to a packing plant and slaughtered

early the next morning. The head and leaf fat were removed at slaughter. Backfat measurements were taken on the carcasses the same day they were slaughtered. Cold carcass weight and weights of the lean cuts were taken about 27 hours after slaughter.

Results

The means and the standard deviations for the measurements of fatness and for the carcass data are given in table 1. The carcasses of the gilts were 12.1 lb. heavier than those of the barrows, but there was relatively little difference in the percentage lean cuts or carcass backfat. While the sex difference for any of the probe measurements is small, there is some indication that the barrows were a little fatter behind

TABLE 2. PARTIAL CORRELATIONS BETWEEN DIFFERENT SITES OR METHODS OF PROBING AND CARCASS ITEMS

Variable	Percent lean cuts	Percent ham	Backfat
Mechanical probe			
Shoulder	—.806	—.755	.746
Back	—.824	—.716	.760
Loin	—.752	—.593	.722
Average	—.890	—.778	.832
Ultrasonic (2.5 mc/s)			
Shoulder	—.718	—.634	.656
Back	—.785	—.644	.692
Loin	—.816	—.773	.698
Average	—.900	—.750	.755
Ultrasonic (1.5 mc/s)			
Shoulder	—.735	—.665	.726
Back	—.663	—.518	.763
Loin	—.584	—.562	.628
Average	—.761	—.667	.749
Carcass backfat	—.847	—.746	—
Percent ham	.964	—	—

the shoulder and slightly less fat over the middle of the back. Further statistical analyses were restricted to differences within each of the two sexes.

The correlations between the three methods of probing and percent lean cuts, percent ham and carcass backfat are given in table 2. These have been adjusted for differences in carcass weight and were computed on a within sex basis. Differences between breeds are included in these correlations. From a statistical standpoint, all of these correlations are much larger than is required for the .01 level of significance.

The flaw detector was calibrated so that the time required for sound waves to rebound through an aluminum rod 5.5 in. long was equal to an oscilloscope reading of 5.0. Warm fat at a depth of 1.6 in. from recently

killed pigs had an average reading on the oscilloscope of 6.0 units. Thus the speed of sound through aluminum is $\left(\frac{6.0}{1.6}\right) \cdot \left(\frac{5.0}{5.5}\right) = 4.125$ times as fast as the speed of sound through fat.

The oscilloscope reading of 6.0 units for 1.6 in. of fat corresponds to a change of 3.75 units on the oscilloscope for each inch of warm fat including the skin. This value can be compared with two regressions computed from the 56 pigs in the present study. The regression of oscilloscope reading on average carcass backfat was 3.71 units, while that on average mechanical probe was 3.60 units. Since the mechanical probes were made at sites which correspond closely with those of the ultrasonic readings, it seems that this latter regression should correspond closely to the 3.75 units computed directly from physical measurements.

Discussion

Both the mechanical probe and ultrasonic method at 2.5 mc/s gave extremely high correlations with percent lean cuts. The mechanical probe was definitely more accurate at the shoulder than the ultrasonic probe, while the opposite was true at the loin. An effort was made to penetrate the trapezius (false lean) with the mechanical probe at the shoulder, since Holland and Hazel (1958) indicated that inconsistencies here could be a major source of error. With the ultrasonic probe, even slight twitches of the body are reflected in an irregular and wavering line on the oscilloscope. This was much more pronounced at the shoulder than at the back or loin. Further work with the ultrasonic method may indicate that sites for measurements should be concentrated more nearly in the back and rear of the body than has been the case with the mechanical probe.

Ultrasonic measurements at a frequency of 2.5 mc/s on the back and loin were more highly correlated with percent lean cuts than were those for corresponding sites taken at 1.5 mc/s.

One of the noticeable things in table 2 is that the different probe measurements are definitely more highly correlated with percent lean cuts than they are with percent ham. The highest correlation between fat measurement at an individual site and percent ham is the ultrasonic measurement at 2.5 mc/s at the loin. Since ham makes up a large portion of the entire value of the carcass, an effort was made earlier to establish a mechanical probing site on the ham (Hazel and Kline, 1953) without great success. Mechanical probes taken on the side of the ham gave a correlation with percent lean cuts of only —.29.

In view of the demonstrated high accuracy of the mechanical and electrical probe techniques for measuring percent lean cuts, the ultrasonic method, although equally accurate, may not have very extensive usefulness for measuring fatness in swine. However, there are two additional possibilities for its use with swine. One is on young pigs that have

relatively small amounts of fat. Neither the mechanical or electrical methods have worked very successfully in those cases. The other possibility is that accurate probing sites can be established on the ham which will actually reflect more accurately the true value of the carcass. Preliminary trials have been tried using the ultrasonic method on beef cattle, but these have not been very successful.

Summary

Mechanical probes and ultrasonic fatness measurements were made on 56 market pigs. The probing sites were about 2 in. off the midline of the body behind the shoulder, at the middle of the back and at the rear of the loin. After removing differences due to sex and carcass weight, the correlations between average ultrasonic probe at a frequency of 2.5 mc/s and percent lean cuts was —.90. The corresponding correlations with probes as a frequency of 1.5 mc/s was —.76 while that with the mechanical probe was —.89. In particular, the ultrasonic probe at the loin (2.5 mc/s) gave a high correlation with percent ham.

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A STATISTICAL STUDY OF RELATIONSHIP, INBREEDING, GESTATION LENGTH, AND CALVING INTERVAL IN A HERD OF ABERDEEN-ANGUS CATTLE

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THE purebred Aberdeen-Angus herd at the Agricultural and Mechanical College of Texas was established in 1906 when two cows were purchased. From 1906 to 1947, the years reported in this study, only four other cows were added to the herd. During this period most of the female replacements were selected from within one particular cow family, as in 1949 all but two of the 29 cows in the herd had descended from one foundation female. The sires were brought in from outside the herd in an attempt to avoid inbreeding.

The purpose of the study was to determine what effect such a breeding system had upon the inbreeding and relationship coefficients, to estimate heritability of gestation length, and to calculate repeatability of gestation length and calving interval.

Data and Methods

The data were pedigree records for 350 calves born during the years included in the study, 282 calving intervals (67 cows represented), and 202 gestation records.

The inbreeding coefficient for each calf and the yearly *inter se* relationship among the female offspring were calculated. An estimate of heritability of gestation length was calculated from the half-sib correlation. Intraclass correlations were used as repeatability of gestation length and calving interval. The data were not corrected for sex of the calf as sex differences were not statistically significant. It seems likely that if yearly differences were important they might increase the intraclass correlation for sires, whereas they might decrease the intraclass correlation for dams.

Results and Discussion

Inbreeding and Relationship. The first calf from related parents, a result of its sire being slightly related to a sire used previously, was born in 1929. Inbreeding was almost completely avoided, since the average inbreeding coefficient was 2.16% for the 182 bull calves and 2.12% for the 168 heifer calves. The overall average was 2.14%. The inbreeding

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coefficient for the herd, from 1906 through 1939, averaged from 10 to 14% below those Stonaker (1943) calculated for the breed.

The average yearly *inter se* relationship for the heifer calves was 0.27. If during each year only one sire had been used on cows unrelated to each other and to the sire, the yearly *inter se* relationship among the offspring would have been 0.25. However, since two or more males sired calves during 15 of the 41 years, the high average relationship among the females was undoubtedly a result of the dams having descended from the one foundation cow. The yearly *inter se* relationships for the females born in the herd (1906 through 1939) were from 10 to 17% above values Stonaker (1943) reported for the breed.

Calving Interval and Gestation Period. The 282 calving intervals averaged 424 days and the standard deviation was 132 days. Deducting

TABLE 1. ANALYSIS OF VARIANCE OF CALVING INTERVALS

Source of variation	D/F	M.S.	Composition of mean sq.[a]
Total	281		
Between cows	66	24554*	E+4.18 C
Within cows	215	12167	E

* $P<.01$.

[a] E=12167=Variance caused by intracow differences. C=2964=Variance caused by differences among cows. Repeatability $=\frac{2964}{2964+12167}=.20$.

the average gestation length, 279.5 days, from the average calving interval leaves an average of 144.5 days of the calving interval over which the breeder has partial control. The correlation between gestation period and the portion of the calving interval exclusive of the gestation period was −.03. The length of this period can be affected by many factors such as the desire to have purebred calves dropped shortly after the show ring classification dates, the dislike for summer calves, the nutritional levels, partial sterility in the cow or the bull, and possibly others.

Repeatability of calving interval was obtained by using the variance components derived from the analysis of variance shown in table 1.

The standard error for this highly significant correlation, 0.20, is approximately 0.05 (Fisher, 1950).

The simple correlation (based on 43 degrees of freedom, since birth dates were available for only 45 of the cows) between the age of the dam (in months) when her first calf was born and her average calving interval was 0.29 (practically significant at the 5% level) with a standard error of 0.10.

A highly significant correlation of −.37 was obtained between length of gestation and the chronological day of the year on which the calf was born. These results differed from those reported by Knapp *et al.* (1940),

where, in beef Shorthorns, the longest gestation periods preceded the fall calvings, but were in agreement with those obtained by Brakel *et al.* (1952). The latter investigators found that for dairy cattle, when grouped according to month of calving, gestations preceding spring calving were significantly longer (2.07 days) than those preceding autumn calvings.

According to Williams (1927), the duration of pregnancy tends to vary with the health and vigor of the dam which depends upon heredity and numerous aspects of the environment. Heritability estimates are calculated to determine the relative importance of hereditary differences in influencing variation in the duration of pregnancy. Variance components used to estimate heritability of gestation length were derived from the analysis of variance of gestation length presented in table 2.

TABLE 2. ANALYSIS OF VARIANCE OF GESTATION LENGTH

Source of variation	D/F	M.S.	Composition of mean square[a]
Total	201	42.3	
Between sires	5	198.8*	E+1.56 D+23.20S
Between dams w/n sires	110	42.5	E+1.74 D
Between full sibs	86	32.9	E

* $P<.01$.

[a] E=32.9=Variance within sets of full sibs. D=5.5=Extra variance among paternal half sibs as compared with that among ful sibs. S=5.6=Extra variance among non-sibs as compared with that among paternal sibs.

Since D and S are practically equal, heritability estimates based on the maternal half-sib correlation, the paternal half-sib correlation, and the full-sib correlation would be almost identical. The other two possible estimates would be approximately the same as the one based on the full-sib correlation, $2(S+D)/(S+D+E)$, which is 0.50. The approximate fiducial limits, (Bross, 1950) were 0 and 11 for the dam component and 2 and 30 for the sire component.

Repeatability of gestation length, calculated from the same data, was 0.18 with a standard error of about 0.09 (Fisher, 1950). This value compares favorably with the repeatability of 0.29 reported by Jafar *et al.* (1950), for Holstein-Friesians. The analysis of variance of gestation length from which the variance components, used to obtain repeatability, were obtained is shown in table 3.

Estimating heritability from the sib correlation treats gestation length as a characteristic of the calf, whereas repeatability treats gestation length as a characteristic of the dam since, operationally, it is the correlation between gestation lengths of maternal sibs. Theoretically, repeatability should equal or be larger than heritability. Since the present heritability estimate is so much larger than repeatability and since the variance components, from which heritability was estimated, had relatively large fiducial limits, the accuracy of the present heritability estimate of 0.50

is questionable. However, this value does not differ appreciably from results reported by Jafar *et al.* (1950). After analyzing gestation records for Holstein-Fresians, they concluded that variation in the combined heredity of the calf (excluding sex) and the dam was responsible for 50 to 70% of the total variance. The heritability estimate of 0.50 also equals that reported by Wheat and Riggs (1957) for heritability of gestation length when based on the paternal half-sib correlation. If heritability is even approximately as high as these estimates, it would be possible to change the length of gestation by selection, but eventually the extremes in gestation length might approach pathological conditions.

TABLE 3. ANALYSIS OF VARIANCE OF GESTATION LENGTH

Source of variation	D/F	M.S.	Expected mean square[a]
Total	201	42.3	
Between cows	78	53.3*	E+2.41 C
Within cows	123	35.3	E

* $P<.05$.

[a] E=35.3=Variance among maternal sibs. C=7.5=Extra variance among non-sibs, as compared with maternal sibs. Repeatability $=\frac{7.5}{35.3+7.5}=0.18$.

Summary

Pedigree records were studied for 350 calves born from 1906 to 1947 in the purebred Aberdeen-Angus herd at the Agricultural and Mechanical College of Texas. In this herd where an attempt was made to keep inbreeding to a minimum, the average inbreeding coefficient was 2.14%. Since practically all the female replacements descended from one particular cow, the average yearly *inter se* relationship among the heifer calves was 0.27, although two or more bulls were used during 15 of the 41 years.

The 282 calving intervals averaged 424 days with a standard deviation of 123 days. Repeatability of calving interval was estimated to be 0.20. The estimate of correlation between the age of the dam (in months) when her first calf was born and her average calving interval was 0.29.

The estimate of correlation between the chronological day of the year on which the calf was born and the length of time it was carried *in utero* was −.37. Heritability estimates of gestation length obtained by quadrupling the paternal half-sib correlation, quadrupling the maternal half-sib correlation and doubling the full-sib correlation were all approximately 0.50. Repeatability of gestation length was estimated to be 0.18.

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THE INFLUENCE OF A THYRO-ACTIVE COMPOUND IN DIETS FOR SWINE DURING LACTATION

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CONSIDERABLE interest has been directed toward the influence of thyro-active compounds on the lactation performance of ruminants. Such compounds have been shown to stimulate the milk production of dairy cattle, if administered either orally or by injection. The role of thyroidal materials in animal production has been reviewed by Blaxter *et al.* (1949). Experiments conducted with lactating swine have been quite limited. A brief report by Reineke and McMillen (1946) indicated that feeding "Protamone" containing 3.16% thyroxine activity as 0.005% of the diet markedly stimulated the milk production of two poor-milking sows. Since the baby pig depends on the sow's milk for its nutriment, it would be of practical significance, if the lactation performance of sows could be stimulated by feeding a thyro-active compound.

The experiments reported herein were conducted to determine the influence of feeding a thyro-active compound on the lactation performance of normal swine.

Experimental

Nine experiments involving 134 sows and gilts were conducted in this study. The two treatments in each experiment were the control diet and the control diet plus 100 mg. of iodinated casein per pound. The three control diets employed are described in table I. The level of 100 mg. of iodinated casein per pound of diet was chosen on the basis of work reported by Johnson *et al.* (1957). The iodinated casein contained 1% thyroxine activity. The control diet used in each experiment is given in the tables of results. Experiment I involved gilts only while in all other experiments both gilts and sows were included.

Experiments 1, 2 and 3 were initiated on the 109th day of gestation and continued until the pigs were 2 weeks of age in experiments 1 and 3, and 1 week of age in experiment 2. The sows or gilts were maintained in individual farrowing stalls, except when allowed access to water and self-feeders as a treatment group twice daily. The pigs were not allowed access to creep feed.

Experiments 1a, 2a, and 3a were continuations of experiments 1, 2 and 3, respectively, since some of the sows or gilts from the latter experi-

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ments were continued on their initial treatments until the pigs were 6 weeks of age in experiments 1a and 2a, and 5 weeks of age in experiment 3a. Experiments 1a and 2a were conducted on rye pasture with two sows and their litters per one-quarter acre. Each pasture lot was provided with an enclosed shelter. The sow diets, creep feed, and water were provided *ad libitum*. Experiment 3a was conducted in individual farrowing stalls,

TABLE 1. PERCENTAGE COMPOSITION OF THE CONTROL DIETS

Ingredients	Sow diets[a]			Creep diet
	No. 1	No. 2	No. 3[b]	
Ground yellow corn	26.5	80.0	77.50	21.15
Ground oats	26.0	....	.....	....
Wheat bran	26.0	....	.....	....
Rolled oats	....	....	.....	35.0
Soybean oil meal (44%)	....	17.0	16.469	25.0
Corn oil	....	....	3.000	....
Alfalfa meal, dehydrated	10.0	....	.....	....
Meat scrap (55%)	6.5	....	.....	....
Linseed meal	4.0	....	.....	....
Cane sugar	....	....	.....	15.0
Steamed bone meal	....	1.50	1.453	1.0
Ground limestone	....	0.75	0.727	1.0
Antibiotic and B_{12} suppl.[c]	0.5	....	.....	1.0
B-vitamin suppl.[d]	....	0.05	0.073	0.05
B_{12} suppl. (6 mg./lb.)	....	0.20	0.294	....
Vitamin A & D suppl. (4000A–500D)	....	....	.....	0.30
Trace mineralized salt	0.5	0.50	0.484	0.50
	100.0	100.00	100.000	100.00

[a] The experimental diets consist of the respective control diet plus 100 mg. of iodinated casein per pound.

[b] Diet No. 3 consisted of 96.875 parts of diet No. 2, 3 parts corn oil, 0.025 parts of the B-vitamin supplement plus 0.10 parts of the B_{12} supplement.

[c] The supplement contained 1.8 gm. of chlortetracycline hydrochloride and 1.8 mg. of vitamin B_{12} per pound.

[d] The supplement contained the following amounts of vitamins per pound: Riboflavin 2 gm., pantothenic acid 4 gm., niacin 9 gm., choline chloride 10 gm., folic acid 60 mg.

the management practices remaining the same as in experiment 3. The pigs in this experiment did not receive creep feed. The sows and gilts of experiments 2a and 3a were placed in drylot with access to water only for 48 hours at the termination of the experiment to obtain information as to the relative intestinal fill which could be attributed to the treatments.

Experiments 4, 5 and 6 were initiated when the litters were 2 weeks of age and continued until weaning at 6 weeks. Experiment 6 was conducted in individual, concrete-floor pens. A shelter 6 ft. by 7½ ft. was provided for each sow or gilt and litter. Experiments 4 and 5 were conducted in one-acre alfalfa pasture lots. There were three sows and litters per lot in both experiments, except that four sows and litters were in the lot

receiving iodinated casein in experiment 5. Two shelters 7 ft. by 8 ft. and a sunshade 8 ft. by 12 ft. were provided in each pasture lot. Sow diet, creep feed and water were provided *ad libitum* in all three experiments. The sows and gilts of experiments 4 and 5 were placed in drylot for a 48-hour shrink period as previously described for experiments 2a and 3a.

Individual pig and sow or gilt weights were recorded in all experiments.

Results and Discussion

The results of experiments 1, 2 and 3 are given in table 2. With the exception of experiment 3 from initiation of the experiment until farrowing, the group receiving iodinated casein lost considerably more weight

TABLE 2. SUMMARY OF RESULTS OF EXPERIMENTS 1, 2, AND 3

Items	Hybrids—1		Durocs—2		Durocs—3	
	Control	I.C.[b]	Control	I.C.	Control	I.C.
Experiment terminated, post partum	2 weeks		1 week		2 weeks	
Control diet number	1		1		3	
No. of sows[a]	17	16	10	11	4	5
Av. initial wt., lb.	417.1	409.1	560.0	531.8	664.8	592.8
Av. wt. change, to farrowing, lb.	−21.5	−29.1	−33.0	−50.4	−28.5	−28.4
Av. wt. change, farrowing to finish, lb.	−18.2	−36.2*	−16.0	−34.6	−13.0	−34.6
Av. total wt. change, lb.	−39.7	−65.3*	−49.0	−85.0*	−41.5	−63.2
Av. daily feed, lb.	7.6	5.8	6.6	4.7	11.1[c]	9.8[c]
Pigs per litter farrowed	9.9	8.6	9.1	10.2	10.2	8.4
Pigs per litter finishing	8.5	7.6	7.5	6.5	8.8	7.0
Av. initial pig wt., lb.	2.96	2.99	3.15	3.15	2.86	3.04
Av. pig wt. gain, lb.	4.22	4.58	1.84	1.54	4.17	4.40

[a] Number of sows or gilts that finished the experiment.
[b] Iodinated casein.
[c] Represents average daily feed intake of experiments 3 and 3a.
* Significantly different from the control, $P<0.05$.

than the control group in all phases of the three experiments. This weight loss was significantly different ($P<0.05$) from farrowing until termination of the experiment in experiment 1, and for the total weight change in both experiments 1 and 2. A pooled analysis of variance of the three experiments for the weight loss of the sow from farrowing until termination of the experiment showed the weight loss of the group receiving iodinated casein to be significantly greater than that of the control group ($P<0.01$). A similar pooled analysis of pig weight gains showed that there was no significant difference. The data in table 2 indicate that the sows receiving iodinated casein did not consume as much feed, which could have materially affected their body weight loss. It seems of special importance that the highly fortified diet, diet 3, did not seem materially to affect the results.

The results of experiments 1a, 2a, and 3a as given in table 3 follow the same trend as those of the previous experiments. It should be pointed out that the sows in these experiments were initially started on treatment on the 109th day of gestation and the results of the first portion of the

TABLE 3. SUMMARY OF RESULTS OF EXPERIMENTS 1a, 2a, AND 3a

Items	Hybrids—1a		Durocs—2a		Durocs—3a	
	Control	I.C.[b]	Control	I.C.	Control	I.C.
Experiment initiated, post partum	2 weeks		1 week		2 weeks	
Experiment terminated, post partum	6 weeks		6 weeks		5 weeks	
Control diet number	2		2		3	
No. of sows[a]	10	6	10	9	4	5
Av. initial wt., lb.	364.0	320.0	511.0	425.5	623.3	529.6
Av. wt. change, lb.	27.5	9.2	20.0	3.9	−3.3	−10.6
Av. 48-hr. shrink, lb.	.....	.....	−33.2	−23.7	−31.3	−28.0
Av. wt., total	27.5	9.2	−13.2	−19.8	−34.6	−38.6
Av. daily feed, lb.	14.8	14.2	11.9	12.9	11.1[c]	9.8[c]
Pigs per litter	8.0	8.2	5.8	5.1	8.5	6.8
Av. initial pig wt., lb.	8.21	7.67	5.32	5.00	7.12	7.55
Av. pig wt. gain, lb.	14.17	12.10	14.29	15.01	6.41	7.76
Av. creep intake/pig/day, lb.	0.42	0.42	0.09	0.16	No creep	

[a] Number of sows or gilts that finished the experiment.
[b] Iodinated casein.
[c] Represents average daily feed intake of experiments 3 and 3a.

lactation period are given in table 2. As in the previous experiments, table 3 shows that those groups receiving iodinated casein either failed to gain as much weight or lost more weight than the control group; however, this effect was not statistically significant. In experiments 2a and 3a, the group receiving iodinated casein did not show a 48-hour shrink as great as the controls. This may indicate that part of the difference in weight change was due to a difference in the intestinal fill. However, the difference in shrink was not of sufficient magnitude to account for the total difference in weight change, especially if the results of the first portion of the lactation period, given in table 2, are taken into account. In experiments 1a and 2a the group receiving iodinated casein consumed as much sow feed as the controls. The data of experiment 3a represent an average of the daily feed intake of both experiments 3 and 3a and may not be a true representation of this portion of the lactation period.

TABLE 4. SUMMARY OF RESULTS OF EXPERIMENTS 4, 5 AND 6

Items	Yorkshires and Hampshires—4[a]		Yorkshires—5		Crossbreds—6	
	Control	I.C.[b]	Control	I.C.	Control	I.C.
Control diet number	2		3		2	
No. of sows	6	6	3	4	4	4
Av. initial wt., lb.	495.0	388.3	440.0	393.7	351.2	337.5
Av. wt. change, lb.	−61.6	−52.5	−43.3	−36.3	12.5	−18.8[c]
Av. 48-hr. shrink, lb.	−28.3	−30.0	−26.0	−26.3	.....	.....
Av. total wt. change, lb.	−89.9	−82.5	−69.3	−62.6	12.5	−18.8
Av. daily feed, lb.	5.7	6.4	8.3	9.6	12.3	13.4
Pigs per litter	9.7	8.3	10.7	10.0	8.2	9.8
Av. initial pig wt., lb.	8.06	7.04	8.39	8.37	7.68	7.23
Av. pig gain, lb.	13.74	13.63	9.50	9.66	10.25	11.12
Av. creep intake/pig/day, lb.	0.29	0.35	0.19	0.15	0.11	0.12

[a] Two Hampshires in the control group and one in the experimental group.
[b] Iodinated casein.
[c] Significantly different from the control ($P<0.05$).

As in the previous experiments, there was no significant response in regard to pig weight gains.

Experiments 4, 5, and 6 were initiated at 2 weeks postpartum and continued until weaning. The results of these experiments are given in table 4. In experiment 6, which was conducted in drylot, the experimental group receiving iodinated casein lost weight while the controls gained weight; this was statistically significant ($P<0.05$). In experiments 4 and 5, there were no differences either in regard to weight change while on experiment or during the 48-hour shrink. This fact would seem to indicate that alfalfa pasture has an influence on the response to iodinated casein or a breed effect has been encountered since the predominant breed was Yorkshire. The feed intake of the experimental group receiving iodinated casein in these experiments was somewhat greater than that of the controls. As encountered in all previous experiments, there was no significant effect on pig weight gains due to treatment.

The finding that feeding thyroprotein to the sow failed to influence nursing pig gains is contrary to the work reported by Johnson *et al.* (1957). The Iowa workers used a different diet; however, in our opinion the variation in diets is not of particular importance.

Summary

Nine experiments were conducted to determine the effect of including iodinated casein (1% thyroxine activity) at 100 mg. per pound of diet for lactating sows and gilts. Feeding iodinated casein failed to influence pig weight gains when initiated at either the 109th day of gestation or 2 weeks post partum and continued until weaning at 5 or 6 weeks. However, it caused a greater weight loss or reduced weight gain of the sow or gilt in all experiments in which Durocs, crossbreds, or hybrids were used. This response was not observed in experiments in which Yorkshire was the predominant breed.

The increased weight loss or decreased weight gain produced by feeding iodinated casein was usually associated with a decreased feed intake and could not be entirely attributed to differences in intestinal fill.

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A PNEUMATIC PLUG FOR RUMEN FISTULAS

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THE advantages of using fistulated animals for the collection of rumen contents are widely recognized. The desirability of closing rumen fistulas is well known, and has been discussed by Phillipson and Innes (1939). Closure of the fistula is particularly important in studies of the rumen microflora, since the presence of air and the loss of ingesta produce undesirable effects.

In general, most of the mechanical devices which have been described for closing fistulas fall into one of three types; (a) a flap of leather or rubber inside the rumen, attached to a block of wood or cork protruding through the fistula opening and fastened to a flat piece of wood on the outside; (b) a cannula of metal or plastic held in place by flanges or clamps on both the inside and the outside of the rumen wall; and, (c) pneumatic plugs which are inserted into the fistula and inflated. Mechanical plugs of the first type have been described by Schalk and Amadon (1928); cannulas have been used by Quin, Van der Wath and Myburgh (1938), Phillipson and Innes (1939). Stoddard *et al.* (1951), and by Hentshl *et al.* 1954. Phillipson and Innes (1939) employed also a pneumatic plug which consisted of a football bladder held in the middle by an ivory ring which fitted the rim of the fistula. Pneumatic stoppers were also designed and used at the Ohio Station during the 1930's but details of these plugs were not described in the literature. They were manufactured by one of the commercial rubber companies, employing specially contructed molds (Bentley, 1958). A pneumatic stopper was devised by Cole, Mead, and Kleiber (1942) for use in studying ruminal pressure. This device was designed for a highly specialized purpose; however, and its construction also required a special mold.

Previous experience with mechanical stoppers and cannulas led us to the belief that pneumatic plugs offered the advantage of being more convenient to remove and replace than the stoppers, and of affording better access to the rumen than cannulas. One of the disadvantages of these plugs, however, is the cost of special molds for their construction. It was our purpose, therefore, to develop a pneumatic fistula plug which would be both practical and inexpensive, and which could be fabricated with materials and facilities available locally.

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[3] The authors express their appreciation to Dr. F. C. Neal for his valuable suggestions and for fistulating the animals, and to Dr. Orville G. Bentley for furnishing information concerning the pneumatic plugs formerly used at the Ohio Station.

Construction

The material used was obtained from discarded automobile and truck inner tubes. All cutting and vulcanizing operations were performed either in the laboratory or in a local tire shop. During vulcanization, close adherence to the desired dimensions was obtained by painting all surfaces not to be vulcanized with "curing tube and bag paint"—a chalky paint used to prevent curing tubes from adhering to tires during retreading.

The first design tested consisted of a rubber bladder constricted at the center to give the shape of an hour-glass. This plug was easily constructed,

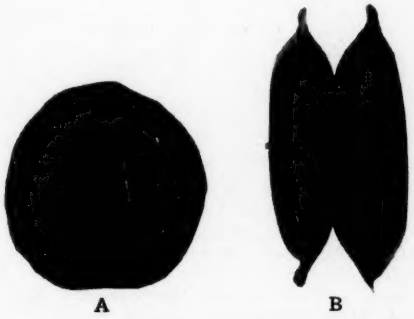

Figure 1. Pneumatic rumen fistula plug made from tire inner tubes.
A. Outside view.
B. Side view.

but when put into use it was found to protrude excessively from the animal's side. Also, since it exerted its pressure directly on the edges of the fistula, necrosis developed around the fistula after a few days. It was then decided that a plug should be designed so that the pressure was exerted between the inside and outside sections of the plug for one or two inches around the circumference of the opening rather than directly on the periphery of the fistula.

The design show in figure 1 was finally developed. When inflated, this plug exerted pressure on both the inside and outside walls of the rumen for some distance around the fistula opening, but not directly on the circumference itself. Also, the construction was of such a nature that the plug did not protrude excessively from the animal's side.

Details of the construction are shown in figures 2, 3 and 4. The dimensions shown are satisfactory for a fistula approximately 6 in. in diameter. The patterns representing the inner walls, outer walls, and the components of the pressure strap were each cut in duplicate. Rubber from truck or tractor tubes was used for the two outside walls of the plug

(parts B, figure 2) while the more pliable automobile tubes furnished the rubber for the inner walls (part A, figure 2). The heavy rubber used for the end walls resisted distention of the plug into the rumen or to the outside, while the more flexible rubber used for the inner walls expanded toward each other to form a seal when the plug was inflated. The curved shapes indicated in the cross section (figures 3 and 4) are

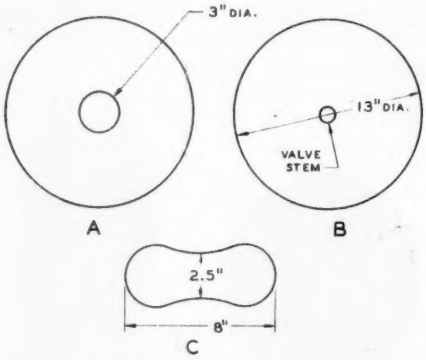

Figure 2. Basic parts of the pneumatic plug.
A. Inner walls.
B. Outside or end walls.
C. Pressure strap.
Each of these parts was cut in duplicate.

representative of the actual shape of these parts when they are cut from the outer circumference of tire tubes.

A valve stem was vulcanized into the center of one of the end pieces then the two end walls were fastened together in order to prevent their undue distention when the plug was inflated. This was accomplished by vulcanizing together both pieces of the pressure strap throughout most of their length, folding back the four free ends and vulcanizing them to the centers of the outside walls, as shown in figure 3.[4]

The inner walls were put together by cutting a hole approximately 3 in. in diameter in the center of each piece, and vulcanizing the two pieces together around the periphery of the holes. Final assembly was accomplished by drawing one of the end walls through the hole in the two inner walls, and joining each inner wall to its respective outer wall around the circumference (figure 4). This was done by a series of vulcanizing operations in which a short section was sealed each time. Irregularities were trimmed and the edges were smoothed by buffing.

[4] Stability of the plug would probably be improved by attaching a rubber tab from the center of the pressure strap to the edge of the hole which connects the inner and outer compartments. This would restrict the movement of the pressure strap through the hole.

The final step was to make a stiff rubber band to fit tightly around the plug at the junction of the inner and outer compartments. The rubber band served a two-fold purpose; primarily, it eliminated the sharp V shape of the pressure groove, which had a greater tendency to cause necrosis of the fistula; and, secondarily, it helped to prevent stretching of this groove by the air pressure. It was made by cutting a strip ½ in. to ¾ in. wide from a thick tractor inner tube, just long enough to stretch around the 5 in. diameter circle, and vulcanizing the ends of the

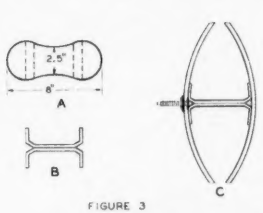

FIGURE 3

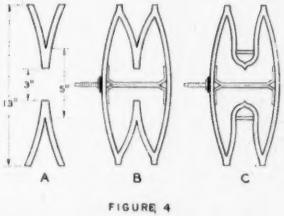

FIGURE 4

Figure 3. Construction and installation of the pressure strap.
- **A. Top view of pressure strap.**
- **B. Side view of pressure strap, showing the two pieces of rubber vulcanized together with ends bent back.**
- **C. Cross section showing pressure strap vulcanized to the two end walls.**

Figure 4. Details of assembly of plug.
- **A. Inner walls vulcanized together around periphery of central hole.**
- **B. Inner and outer walls joined.**
- **C. Assembled plug with spreader band in place.**

strip together. The completed rubber band was easily positioned on the deflated plug. The completed plug is shown in figure 4C.

Installation of the plug was accomplished by folding the inner compartment of the deflated plug and pushing it through the fistula. The plug was then positioned by rotating, pushing, and pulling to straighten the inside section. A tire pump was used to inflate to the proper pressure.

Results and Discussion

Pneumatic plugs of the type described above have been used successfully to close fistulas in the bovine rumen for more than a year. The greatest advantage of this type of plug is the ease with which it may be inserted and removed to leave a large opening into the rumen. In addition, its flexibility reduces the chances of injury to the animal, and the fact that it can close the fistula tightly for short periods of time makes it more versatile.

Healing of the surgical wound after fistulation was found to be more

rapid when a plug of the type described by Shalk and Amadon (1928) was used. The pneumatic plug was then installed in the fully healed fistula. We have used the pneumatic plug when samples are to be taken frequently, and employed a mechanical plug during periods when they are not.

It is obvious that an inflated rubber plug is susceptible to damage from fences and sharp objects, but this fragility has been minimized by the use of heavy rubber on the outside wall. Punctures which have occurred were easily repaired with inner tube patches. When the plug was carefully made, and the animals were cared for daily, as any fistulated subjects should be, the pneumatic stopper was found to be as reliable as any of the other types previously used, and was considerably more convenient. It has been our experience that the temperament of a fistulated subject has a considerable influence on the retention of any rumen fistula plug, and a docile, easily managed animal should be chosen for fistulation.

One difficulty in the use of the pneumatic plug is in inflating it to the proper pressure. A high pressure in the plug will seal the fistula effectively but will cause necrosis. It is necessary to use just enough pressure to hold the plug in place and seal the fistula without interfering with blood circulation. The correct amount of pressure can be ascertained by experimenting, and one soon develops a "feel" for it. The pressures employed in our plugs are too low to register on a tire gauge. Properly inflated, the plug will be somewhat soft; not distended as a football bladder. With the plug thus inflated, a small amount of leakage of rumen fluid usually occurred, but this was not noticeably greater than that occurring with other types of rumen closures.

Equal pressures in the two compartments of the plug were attained by making fairly accurate measurements of their dimensions so that both sides were of equal volume. Careful marking and symmetrical vulcanizing greatly improve the stability of the plug. When there is excessive gas production of the particular ration used and the plug is blown out, a convenient remedy is to make the inside compartment of slightly greater diameter, and therefore of greater volume. This causes the plug to be pulled inward slightly and resist the gas pressure in the rumen.

Some attention to the care and positioning of the pressure strap connecting the two end walls was necessary. This strap was made as short as possible so that the plug would not protrude excessively from the animal's body. There is a minimum allowable length of the strap, however, because of the difficulty in maintaining equal pressure in each compartment. If the strap was too short (less than 3 in. for plugs of these dimensions) one side was pulled in more than the other with consequent instability. If the pressure strap was not attached exactly in the center of the two end walls, the unequal pull caused one compartment of the plug to collapse and the other to spread.

Summary

The construction of a pneumatic plug for bovine rumen fistulas is described. The plug is inexpensive, requires no special molds, and can be fabricated in tire repair shops from discarded inner tubes. The plug is convenient to remove and replace, and permits excellent access to the rumen. It has been used successfully for more than a year.

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ZINC TOXICITY IN THE WEANLING PIG

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In 1934, Todd *et al.* reported the first evidence of a need for zinc in the diet of animals. They found that the addition of zinc salts to the diet of rats improved the rate of growth. Studies by Sutton *et al.* (1937) showed that the zinc tolerance of the rat was between 0.5 and 1.0% of the diet. Further studies with the rat reported by Smith *et al.* (1946) indicated that feeding zinc carbonate at 1.0% of the diet produced a severe anemia in 3 to 5 weeks, and in another study 0.7% zinc carbonate produced a marked anemia within 4 weeks.

Grimmett *et al.* (1937) and Sampson *et al.* (1942) have both described zinc toxicity in the young pig produced by feeding 0.1% zinc in the form of zinc lactate in a diet consisting largely of milk. However, Sampson *et al.* (1942) failed to produce zinc toxicity in the growing pig during the latter stages of development.

The occurrence of parakeratosis has prompted considerable experimental investigation of the required amount of zinc in the diet of the pig (Stevenson *et al.*, 1956; Lewis *et al.*, 1956; Hoekstra *et al.*, 1956; Lewis *et al.*, 1957; Luecke *et al.*, 1957). It appears that both calcium and zinc are involved in the etiology of this nutritional disorder. At any rate zinc salts are being routinely added to practical swine rations.

The purpose of this study was to ascertain the level of zinc tolerance and to characterize zinc toxicity in the weanling pig. The interaction of high dietary levels of zinc and calcium, and the action of high dietary levels of zinc on the blood clotting time were also investigated.

Experimental

Three experiments were conducted with weanling pigs. A description of the diets used is given in table 1.

Thirty-six weanling pigs of various breeds were used in Experiment 1. Outcome groups of six pigs each were formed on the basis of breeding, weight and general condition. The pigs were allotted at random to the zinc treatments from the outcome groups and self-fed *ad libitum* in treatment groups for 42 days in concrete pens. The zinc treatments imposed are given in table 2.

In Experiment 2, 40 weanling pigs of various breeds were used. Outcome groups of five pigs each were formed on the basis of breeding, weight and

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TABLE 1. PERCENTAGE COMPOSITION OF DIETS FED

Experiment no.	1	2 and 3[a]
Yellow corn, ground	77.2	77.2
Soybean oil meal, solvent	20.3	20.3
Vitamin A & D oil (3000A–600D)	0.5	0.5
Trace-mineralized salt	0.5	....
Iodized salt	....	0.5
Ground limestone	1.0	1.0
Dicalcium phosphate	0.5	0.5
Chlortetracycline, 25 mg./lb.	+	+
Vitamin mixture #37[b]	+	+
Mineral mixture #1[c]	—	+

[a] Contained 46.9 ppm zinc, dry matter basis.
[b] Vitamin additions per lb. of diet were: Thiamine HCl, 0.50 mg.; riboflavin, 1.40 mg.; niacin, 5.0 mg.; calcium pantothenate, 4.5 mg.; pyridoxine HCl, 0.60 mg.; folic acid, 0.35 mg.; inositol, 90.0 mg.; p-amino-benzoic acid, 10.0 mg.; biotin, 0.03 mg.; vitamin B_{12}, 5.0 mg.
[c] $MgCO_3$, 623 mg.; $FeSO_4$, 182 mg.; $MnSO_4 \cdot H_2O$, 54.48 mg.; $CoCl_2 \cdot 6H_2O$, 18.16 mg.; $CuSO_4$, 18.16 mg.; NaF, 3.6 mg.; KI, 1.8 mg.

general condition. The pigs were allotted at random to the zinc treatments from the outcome groups which, in turn, were allotted at random to the calcium treatments. The pigs were self-fed *ad libitum* in individual metal pens with wire mesh floors for 35 days. Calcium was added as 3% dicalcium phosphate which replaced an equal amount of yellow corn. The zinc treatments imposed and the calcium levels are given in table 3.

Sixteen weanling pigs of various breeds were used in Experiment 3. Outcome pairs were formed using the same criteria as in the two previous experiments. The pigs were allotted at random to the zinc treatments from the outcome pairs. Feeding methods and management practices were the same as in Experiment 1. The zinc treatments imposed are given in table 4.

All supplemental zinc was supplied as reagent grade zinc carbonate. Clotting time was measured by the method described by Howell (Wintrobe, 1946). Zinc determinations were performed by the method described in A.O.A.C.

TABLE 2. PERFORMANCE OF WEANLING PIGS FED ZINC CARBONATE. EXPERIMENT 1

Lot number	1	2	3	4	5	6
Zn added, %	0	0.05	0.10	0.20	0.40	0.80
No. of pigs	6	6	6	6	6	6
Mortality	0	0	0	2	3	1
Av. time on test, days	42	42	42	36.3	33.2	29.5
Av. initial wt., lb.	39	38.5	40.3	38	39.2	36.2
Av. daily gain, lb.	1.56	1.62	1.56	1.24	0.77	0.26
Av. daily feed, lb.	4.35	4.59	4.61	4.05	3.36	1.44
Gain-feed ratio	0.36	0.35	0.34	0.31	0.23	0.18
Hemoglobin values, av.[a]	12.99	12.50	12.39	10.87	13.54	12.55

[a] Gm. per 100 ml. blood.

TABLE 3. PERFORMANCE OF WEANLING PIGS FED ZINC CARBONATE. EXPERIMENT 2.

Zn added, %	No. of pigs	Mortality	Av. time on test, days	Av. initial wt., lb.	Av. daily gain, lb.	Av. daily feed, lb.	Gain-feed ratio
Lot 1–0.0%							
Control	4	0	35	26.75	1.46	4.04	.36
Control+1% Ca.	4	0	35	26.00	1.29	3.35	.39
Av.	4	0	35	26.38	1.38	3.70	.375
Lot 2–0.05%							
Control	4	0	35	28.0	1.46	4.09	.36
Control+1% Ca.	4	0	35	26.50	1.16	3.17	.37
Av.	4	0	35	27.25	1.31	3.63	.365
Lot 3–0.10%							
Control	4	0	35	29.50	1.45	3.89	.37
Control+1% Ca.	4	0	35	26.75	1.48	3.83	.39
Av.	4	0	35	28.13	1.46	3.86	.38
Lot 4–0.20%							
Control	4	0	35	28.25	1.42	3.83	.37
Control+1% Ca.	4	0	35	26.00	1.22	3.31	.37
Av.	4	0	35	27.13	1.32	3.57	.37
Lot 5–0.40%							
Control	4	1	32.75	28.0	0.66	2.56	.26
Control +1% Ca.	4	1	26.75	26.75	0.90	2.81	.32
Av.	4	1	29.75	26.88	0.76	2.68	.29

Results and Discussion

The results of Experiment 1 are presented in table 2.

The control group and the groups fed 0.05 and 0.10% zinc responded about the same in average daily gain, average daily feed and gain-feed ratio. There was no evidence that feeding an additional 0.1% zinc exerted a toxic effect. The addition of 0.2% zinc proved to be toxic, since it depressed average daily gain and average daily feed. Also, there was some indication that the gain-feed ratio was depressed. Compared to 0.2% zinc, pigs fed 0.4% zinc exhibited a greater depression in the measures of performance. Pigs fed 0.80% zinc showed body weight loss and a severely depressed feed intake.

TABLE 4. PERFORMANCE OF WEANLING PIGS FED ZINC CARBONATE. EXPERIMENT 3

Lot number	1	2
Zn. added, %	0	0.40
No. of pigs	8	8
Mortality	0	3
Av. time on test, days	42	38.4
Av. initial wt., lb.	35.25	36
Av. daily gain, lb.	1.52	0.92
Av. daily feed, lb.	3.23	2.61
Gain-feed ratio	0.47	0.35

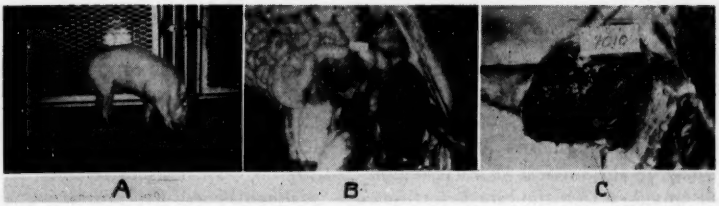

Figure 1. A. Hematoma in left axillary space of a pig fed 0.2% of added zinc. B. Congestion and hemorrhagic condition of the mesenteric tissue. C. Massive hemorrhage in left axillary space.

In the group fed 0.2% zinc, one pig died on the 15th day and another was sacrificed on the 31st day when it showed severe toxic reactions and death appeared imminent. Three pigs died on the next highest level of zinc; deaths occurred on the 15th, 19th, and 31st day of the test. At the 0.8% zinc level, one pig died on the 24th day and the remainder were sacrificed on the 29th or 31st day when they were in an extreme moribund condition.

Pigs fed 0.2% and 0.4% zinc exhibited similar toxic reactions. Typical ante mortem and post mortem gross lesions are shown in figure 1. In general, the pigs exhibited extensive hemorrhage in the axillary spaces. There was a marked gastritis with some ulceration. The intestine contained extensive hemorrhage and there was a marked catarrhal enteritis. The brain was congested and the lateral ventricles contained a large amount of free clotted blood. In addition, the spleen, lymph nodes, and viscera displayed a hemorrhagic condition. Most of the pigs exhibited an arthritic condition

Figure 2. Congestion and swollen joint of pig suffering from zinc toxicosis.

characterized by swollen joints which, on post mortem examination, displayed extensive congestion. Figure 2 shows the syndrome observed.

Pigs receiving 0.8% zinc lost weight the first week of the experiment and started scouring on the third day. The feces were yellow and contained extensive quantities of mucous. Post mortem examination revealed the same general symptoms as described above with marked subcutaneous hemorrhage in the vertical thoracic region. During the post mortem examination it appeared that the blood clotting time was lengthened. Prothrombin time and calcium and phosphorus levels of the blood were studied. Two pigs

TABLE 5. ANALYSES OF VARIANCE OF EXPERIMENTS 1, 2 AND 3

Source of variance	d/f	Mean square		
		Daily gain	Daily feed	Gain-feed ratio
Exp. 1				
Treatment (T)	4	0.8484**		
Outcome groups (G)	5	0.1310		
T x G	20	0.0919		
Exp. 2				
Between diets (D)	1	0.1210	1.7514	0.0024
Groups within diets (G)	6	0.2826**	2.4327**	0.0038
Zinc levels (Z)	4	0.7158**	1.9192**	0.0230**
Z x D	4	0.0619	0.3658	0.0006
Z x G	24	0.0501	0.2822	0.0027
Exp. 3				
Treatment (T)	1	1.5751**		
Outcome groups (G)	7	0.1127		
T x G	7	0.0717		

** Significant at 1% level.

displayed a prothrombin time of 18 seconds, a somewhat shortened time, while the other three were within the normal range. Average calcium and phosphorus levels were 15.7 and 7.6 mg. %, respectively. These values also appear to be within the normal range according to Dukes (1955). Hemoglobin values (table 2) determined on blood taken the 21st day of the experiment appeared to be within the normal range according to Dukes (1955).

The amount of zinc in liver samples was studied. For five pigs fed 0.8% zinc the liver contained 2.26 mg. of zinc per gram of wet tissue. One pig each at levels of 0.2 and 0.4% zinc showed liver zinc values of 1.60 and 3.10 mg. of zinc per gram of wet tissue, respectively.

The analysis of variance, presented in table 5 shows that the treatments exhibited a statistically significant effect ($P<0.01$), upon the weight gains.

The results of Experiment 2 are presented in table 3. The analyses of variance presented in table 5 shows that the zinc levels exhibited a

statistically significant effect ($P<0.01$) upon average daily gain, average daily feed, and gain-feed ratio. The additional calcium did not exert a significant effect, although it may have alleviated the toxicity produced at the highest zinc intake. The performance of pigs fed 0.2% supplemental zinc or less was satisfactory. There was no mortality or evidence of zinc toxicity. However, pigs fed 0.4% supplemental zinc showed depressed average daily gain, feed intake, and gain-feed ratio. Furthermore, one pig died on the 13th day and another pig was sacrificed on the 24th day of the test. Both exhibited symptoms of zinc toxicosis described previously.

It may appear that the determined maximum zinc tolerance may differ in Experiment 1 and 2. In the initial study 0.2% supplemental zinc depressed performance; however, it failed to influence the results in the succeeding study. Perhaps the difference in daily feed intake between the two tests may explain the variation. At the level of 0.2% supplemental zinc, the total daily zinc intake was greater in Experiment 1 than in Experiment 2.

The results of Experiment 3 appear in table 4. This experiment was conducted to determine the effect of a high dietary level of zinc on the blood clotting time. Again, the performance was depressed when 0.4% supplemental zinc was fed. In addition, three pigs died of zinc toxicosis. The analysis of variance, presented in table 5 shows that the treatment exhibited a statistically significant effect ($P<0.01$) upon the weight gains. However, analysis of variance indicated that the blood clotting time was not affected by the addition of 0.4% supplemental zinc to the control diet.

Smith and Larson (1946) observed a relationship between zinc toxicity and dietary copper in rat studies. They deduced from their findings that supplementary copper partially prevents the anemia that develops on diets containing 0.7 percent zinc without preventing the growth depression. On the other hand, liver extract produced a marked growth improvement without significantly affecting the blood picture. Hence, the level of dietary copper may be an important element in the hematological aspects of zinc toxicity, but it appears unlikely that moderate variations in dietary copper would affect the level of zinc tolerance as indicated by growth.

Summary

Ninety-two weanling pigs were used to determine zinc tolerance and the characteristics of zinc toxicosis. Levels of zinc supplementation, as reagent grade zinc carbonate, up to 0.8% of the diet were fed for 42 days. Corn-soybean oil meal diets were used.

The addition of 0.1% zinc to the diet was the maximum level tolerated. Higher levels produced symptoms of zinc toxicosis. Toxic symptoms were characterized by depressed rate of gain, feed intake and efficiency of gain. In addition, arthritis, extensive hemorrhage in the axillary spaces, gastritis, catarrhal enteritis, congestion of the mesentery, and hemorrhages in the

ventricles of the brain, lymph nodes and spleen were observed. Feeding high levels of zinc frequently caused death within 21 days on treatment. Hemoglobin values determined on the 21st day of the experiment were unaffected by the levels of zinc fed.

Calcium added at 1% of the diet as dicalcium phosphate had no effect upon the level of zinc tolerance or upon the toxic reactions.

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THE USE OF TRIIODOTHYRONINE AS A LACTATION STIMULANT FOR SWINE [1]

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THE results of numerous studies (Reece, 1947; Swanson and Knodt, 1949; Thomas *et al.*, 1949; Aitken, *et al.*, 1953; Thomas *et al.*, 1954; Booth *et al.*, 1947; Thomas *et al.*, 1957) have indicated that various degrees of milk flow stimulation may be obtained through the feeding of iodinated protein to dairy cattle.

Reineke and McMillen (1946) reported that feeding iodinated protein as 0.005% of the ration to poor milking sows increased milk flow, as judged by the external appearance of the sows udder and the condition of the suckling pigs. Johnson *et al.* (1956) reported that when iodinated protein was fed to sows from the 110th day of gestation through the 7th day of lactation at the level of 100 mg. per lb. of feed, the weight of suckling pigs increased 27%. Dudley *et al.* (1957) found that when iodinated protein was fed to gilts from the 109th day of gestation through the 13th day of lactation, at the level of 100 mg. per lb. of feed, the weaning weight of the suckling pigs was increased by only 8.5%. This small increase was not statistically significant.

Tomita and Lardy (1956) studied various analogues of thyroxine with respect to their biological activity with tadpole metamorphosis, goiter prevention (rat) and metabolic rate assay (rats). In general they found that, of the several compounds studied, the triiodo compounds were more active biologically than the corresponding diiodo or tetraiodo analogues. Shellabarger (1955) reported that in the rat L-triiodothyronine was aproximately four times as effective as L-thyroxine in reducing the thyroid enlargement caused by thiouracil feeding. However, in chicks he noted no difference, indicating a species difference in response to triiodothyronine and thyroxine.

In view of the above reports it seemed desirable to test the ability of triiodothyronine to stimulate the milk flow of sows during the early stages of lactation. This increase in milk production would be reflected by heavier pigs at an early age, which in turn would facilitate earlier weaning of these pigs.

Experimental Procedure

Eighty-six sows and gilts representing several breeds but consisting primarily of Durocs, Hampshires and Spotted Poland Chinas were fed in four separate trials in this study. The animals were allotted to either a control

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or a treated group according to breed, age and previous performance and maintained on pasture through the 108th day of gestation. During this period they were hand-fed from 2 to 6 lb. of a complete mixed ration daily, depending on the condition of the animals and the amount and quality of forage available. On the 109th day of gestation the animals were brought to the farrowing barn. Good management practices were used during

TABLE 1. COMPOSITION OF BASAL RATIONS USED [a]

Constitutents	Trial I	Trial II, III, IV
Ground yellow corn	59.44	58.54
Soybean oil meal (44% solvent)	29.05	29.05
Dehydrated alfalfa leaf meal (20%)	5.00	5.00
Ground limestone	0.50	0.50
Steamed bone meal	3.00	3.00
Salt (iodized)	0.50	0.50
Trace mineral mix [b]	0.10	0.10
Chlortetracycline supplement [c]	0.10	....
B-vitamin premix [d]	0.20	0.20
Vitamin A and D premix [e]	2.00	2.00
Vitamin B_{12} supplement [f]	0.11	0.11
Antibiotic premix [g]	....	1.00
	100.00	100.00

[a] Sodium Triiodo-L-thyronine, Merck and Co., Inc.

[b] Trace mineral mix: Calcium carbonate 37.19%, manganese sulfate 22.50%, ferrous sulfate 35.00%, copper sulfate 1.89%, cobalt sulfate 0.50%, zinc sulfate 1.25%, potassium sulfate 1.67%.

[c] Chlortetracycline supplement: American Cyanamid's Aurofac 10-A, containing 10 gm. chlortetracycline per lb.

[d] B-Vitamin premix: Pfizer's Vitamin Supplement No. 2, containing 4,000 mg. riboflavin per lb., 4,000 mg. pantothenic acid per lb., 24,000 mg. niacin per lb., and 90,262 mg. choline chloride per lb.

[e] Vitamin A and D premix: 10 gm. vitamin A (10,000 i.u. per gm.), 2.22 gm. vitamin D (9,000 i.u. per gm.).

[f] Vitamin B-12 supplement: Pfizer's 9+B-12 supplement containing approximately 9 mg. vitamin B-12 per lb.

[g] Antibiotic premix: 10 gm. chlortetracycline, 10 gm. procaine penicillin, and 10 gm. streptomycin sulfate per lb.

farrowing and the sows maintained in the barn on a concrete floor until their pigs were weaned at 14 days of age.

Trial 1. Sixteen mature sows were divided between a control and a treated group prior to farrowing. Beginning on the 109th day of gestation the sows were hand-fed twice daily at the rate of 4 lb. per head per feeding. The control group received the basal ration and the treated group received the basal ration plus 600 mg. of triiodothyronine per ton of feed. Following farrowing the ration was gradually increased from 4 lb. per feeding to the maximum amount the animals would consume within approximately 30 minutes. The basal rations used in the different trials are presented in table 1. The rations contained approximately 19% crude protein, were high in energy and were well fortified with minerals and vitamins. The weights of the sows were recorded on the 109th day of gestation and again

at weaning. Within 24 hours after farrowing the pigs were weighed and ear marked. At 14 days the pigs were again weighed and weaned from the sow. Trial I was conducted from July 6, 1957, through August 20, 1957.

Trial II. Twenty-four mature sows were assigned to this trial in the manner previously described. Except for the addition of an antibiotic premix, the basal ration was comparable to that used in trial I. The control animals received the basal ration and the treated animals received 600 mg. of triiodothyronine per ton of basal ration. Commencing on the 109th day of gestation, the sows were fed 3 lb. of feed per head twice daily instead of 4 lb. as in trial I. After farrowing the feeding procedure was the same as for trial I. The farrowing procedure and the collection of data in trial II was also the same as previously described for trial I. In addition the rectal temperature of the sows was taken daily from the 109th day of gestation through the 13th day of lactation, between 3 and 5 p.m. This trial was conducted from September 26, 1957, through November 7, 1957.

Trial III. In the third trial twenty-nine animals (13 sows, 16 gilts) were studied in the manner described for trial II. The trial was conducted from December 31, 1957, through February 10, 1958.

Trial IV. Twenty-five animals (21 sows, 4 gilts) were used in this trial. The procedure for the management of the animals and the collection of data was the same as previously described for trials II and III. The level of triiodothyronine, however, was reduced from 600 mg. to 300 mg. per ton of feed. The experimental period was from March 6, 1958, through April 22, 1958.

Results and Discussion

The results of the four individual trials and the combined results of this study are presented in table 2. A summary of the statistical analyses of the data is presented in table 3. The feeding of triiodothyronine at either the 600 mg. or the 300 mg. level did not significantly affect the number or the weight of the pigs at farrowing. These results were to be expected since the feeding of triiodothyronine was not begun until the 109th day of gestation. Triiodothyronine, when fed at the rate of either 600 or 300 mg. per ton of feed, did not increase the average number of pigs weaned per litter. In the four trials only small, non-significant differences occurred in the weaning weights of the suckling pigs.

The low weaning weights of the pigs in trial I require comment. During this trial there was a high incidence of udder caking and inflamation in both groups. It is probable that this condition was responsible for the low average weaning weights. Triiodothyronine did not appear to aggravate or prevent this condition in any way as the incidence was approximately the same in the control and treated groups. In subsequent trials this difficulty was not a problem.

The most outstanding variation between the control and treated animals

TABLE 2. THE INFLUENCE OF FEEDING TRIIODOTHYRONINE ON THE LACTATING PERFORMANCE, FEED CONSUMPTION, LOSS IN WEIGHT AND BODY TEMPERATURE OF SOWS

Treatment	No. of mature animals	Av. no. of live pigs farrowed	Av. wt. of pigs when farrowed, lb.	Av. no. of pigs weaned	Pigs weaned, %	Av. wt. of pigs weaned, lb.	Av. daily feed cons. by dams, lb.	Wt. lost by dams, lb.	Av. daily temp. of dams deg. F.
Trial I									
Control	8	9.1	2.9	6.8	74.7	5.6	8.0	—38.5	.....
Treated	8	9.8	2.7	7.9	80.6	5.6	7.8	—58.9	.....
Difference	0	0.7	0.2	1.1	5.9	0	0.2	—20.4	.....
Trial II									
Control	12	8.5	2.8	8.0	94.1	8.3	7.7	—38.5	102.8
Treated	12	8.6	2.9	8.3	96.5	8.3	7.6	—60.8	103.3
Difference	0	0.1	0.1	0.3	2.4	0	0.1	—22.3	0.5
Trial III									
Control	13	8.9	2.9	8.5	95.5	8.1	9.6	—31.6	102.0
Treated	13	8.2	3.0	7.8	95.1	9.0	9.6	—45.1	102.1
Difference	0	0.7	0.1	0.7	0.4	0.9	0	—13.5	0.1
Trial IV									
Control	11	10.7	2.5	9.5	88.8	8.2	10.6	—33.6	102.8
Treated	9	8.3	2.7	7.6	91.6	8.5	10.1	—38.1	102.9
Difference	2	2.4	0.2	1.9	2.8	0.3	0.5	—4.5	0.1
Combined results trials I, II, III, IV									
Control	44	9.3	2.8	8.3	89.2	7.7	9.0	—35.3	102.5
Treated	42	8.6	2.9	7.9	91.9	8.0	8.8	—50.7	102.7
Difference	2	0.7	0.1	0.4	2.7	0.3	0.2	—15.4	0.2

was the greater body weight loss of the treated animals. This loss was statistically significant at the 600-mg. level of triiodothyronine intake. In trial IV where the level was reduced to 300 mg. of triiodothyronine per ton of feed, the loss in body weight by the treated animals was only 4.5 lb. more per animal than the controls. This difference was not statistically significant. A loss in body weight was also observed by Johnson *et al.* (1956), who fed iodinated casein to sows at the level of 200 mg. per lb. of feed, and by Dudley (1957) who fed iodinated casein to gestating, lactating gilts at the level of 100 mg. per lb. of feed.

TABLE 3. SUMMARY OF STATISTICAL ANALYSIS FOR NUMBER AND WEIGHT OF PIGS FARROWED, NUMBER AND WEIGHT OF PIGS WEANED, DAILY FEED CONSUMPTION OF SOWS, WEIGHT LOSS OF SOWS AND BODY TEMPERATURES OF SOWS

	Total		Trials		Treatment		Error	
Source of variation	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.	d.f.	M.S.
Number pigs farrowed per litter	85	7.01	3	7.05	1	9.15	78	6.94
Birth weight of pigs per litter	85	0.17	3	0.52*	1	0.15	78	0.16
Number of pigs weaned per litter	85	6.05	3	5.36	1	4.10	78	6.01
Weaning weight of pigs per litter	85	2.91	3	33.98**	1	2.12	78	1.80
Weight loss of sows	85	500.26	3	1070.25	1	5123.00**	77	433.81
Daily feed consumption of sows	85	2.31	3	37.22**	1	1.22	78	1.07
Body temperature of sows	69	0.52	2	6.78	1	0.97	64	0.32

* Significant at 0.05 level of probability.
** Significant at 0.01 level of probability.

The loss in body weight by the treated animals did not appear to be caused by a decreased appetite. Both the treated and the control animals readily consumed the feed which was offered, and throughout the entire experiment only slight differences were noted in the average daily feed consumption of the two groups. An analysis of variance indicated that these small variations in feed consumption were not significant. The greater weight loss by the treated animals may indicate a speeding up of metabolic processes; however, such was not reflected in increased milk flow as measured by pig gains.

During Trials II, III, and IV the rectal temperatures of the lactating animals were taken daily. In trial II the treated animals had an average body temperature which was 0.5° F. higher than that of the controls. In trials III and IV this elevation in temperature was not observed. A statistical analysis of the data indicated that triiodothyronine at the two levels did not significantly affect the body temperature.

Other than the weight lost by the lactating animals the results of this experiment indicate that there were no adverse effects due to the feeding of triiodothyronine at the level of either 600 or 300 mg. per ton of feed.

Summary

Eighty-six lactating sows and gilts were used in four trials to study the effect of feeding triiodothyronine on early lactation performance as measured by weaning weight and survival of suckling pigs at two weeks of age. Data were also collected on feed intake, weight loss and body temperatures of the lactating animals. The test animals in the first three trials received the basal ration plus 600 mg. of triiodothyronine per ton of feed, and those in the fourth trial received 300 mg.

The results indicate that the feeding of triiodothyronine at the level of either 600 or 300 mg. per ton of feed from the 109th day of gestation through the 14th day of lactation did not affect the number or the weight of the pigs weaned.

The treated animals lost an average of 15.1 lb. more weight per animal during the two-week lactation period. This difference which was significant ($P<.01$) did not result from the consumption of less feed, since feed consumption was approximately equal for the two groups. Weight loss was greater for sows fed 600 mg. triiodothyronine than for those fed 300 mg.

Data on rectal temperatures of the lactating animals did not indicate a significant increase in body temperature due to the feeding of triiodothyronine.

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FEEDING VALUE AND ACTIVITY OF DRIED RUMEN PRODUCTS

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DRIED rumen products (D.R.P.) are among the recent feed additives on the market with claims of beneficial effects when fed to ruminants. Such products are either prepared directly from the rumen contents of slaughtered animals or prepared from laboratory cultures. Little is known about the magnitude of activity of the final mixed products or the value when added to rations at recommended levels for continuous feeding. The experiment presented here was designed to determine the activity of dried rumen products *in vitro* and their effect on rate of gain, feed efficiency and digestibility of rations by sheep fed various kinds of rations.

Experimental

In Vitro Cellulose Digestion. The artificial rumen technique as described by Bentley *et al.* (1954) was used for the *in vitro* comparisons with dried rumen products. One gram of Solka-Floc BW-200, a purified wood cellulose, was used as the fermentation substrate. The medium was similar to that used with suspensions of washed rumen microorganism as described by Kamstra *et al.* (1958). The fresh rumen fluid used as innoculum was obtained from a rumen cannulated steer fed a full feed of good quality alfalfa hay and 2 lb. of ground corn daily. The larger particulate material was removed before innoculation of the flasks by straining the rumen fluid through seven layers of cheese cloth. In the comparison flasks, 1 gm. of dried rumen product was either substituted for the fresh rumen fluid or added to it. Lypholized fresh rumen fluid was also used as a source of rumen microorganisms. Percent digestion of the initial cellulose substrate was used as a measure of activity of the microorganism source being tested. Cellulose was determined by the gravimetric method of Crampton and Maynard (1938).

Feeding and Digestion Trials. Two feeding and digestion trials were conducted to determine the value of a dried rumen product in various rations for sheep. Yearling wethers were used in each trial. A permanent type rumen cannula had been installed in one-half of the wethers for purposes of collecting rumen contents in other studies. The cannulated and noncannulated animals were evenly distributed between treatments. A

[1] The authors wish to acknowledge aid from the following: Poul-An Laboratories, Inc., Kansas City, Missouri for supplying dried rumen products, and the Experiment Station Chemistry Department for analytical assistance. Approved for publication by the Director of the South Dakota Agriculture Experiment Station as No. 408 of the Journal series.

study of these and other cannulated sheep showed that the permanent type rumen cannula did not affect rate of gain or digestibility of the rations.

Trial 1. This trial was conducted in two phases, a high-concentrate phase and a low-concentrate phase. The high-concentrate ration was composed of 74.2% ground oats, 25.0% ground alfalfa hay and 0.8% bone meal and a trace mineral salt mixture. The low-concentrate ration was composed of 75% ground alfalfa hay, 24.2% ground oats and 0.8% bone meal and a trace mineral salt mixture.

The wethers were confined to individual pens and fed all they would consume, without waste, twice daily, the concentrates and roughage being kept in the desired ratio. The oats, bone meal and salt were mixed together in batches of a few hundred pounds prior to feeding and the mixture combined with roughage at time of feeding. Water was offered *ad libitum*.

One group of four wethers received the basal ration and another group of four received the same ration plus a dried rumen product. The dried rumen product was added to the concentrate mixes to supply 375 mg. per lb. of final ration in both the high-concentrate and low-concentrate rations.

Each phase of the feeding trial was designed for two fecal collection periods after periods of about three weeks on the rations without fecal collections. However, periods between collections had to be shortened to about two weeks during the low-concentrate phase because of a shortage of hay. The lambs remained in their respective group during both phases of the trial.

Five-day fecal collection periods were used after the lambs had been given about three days to become accustomed to the collection bags. Total fecal collections were made. A 3% sample of feces was saved daily and kept frozen until the end of the collection period. The feces for each lamb were then thawed and thoroughly mixed. The feeds and feces were subjected to proximate analysis by AOAC methods.

The wethers were brought quickly to a full feed at the beginning of each phase of the feeding trial. Feed consumption during the collection periods was about the same as shown for the feeding trials in table 3, there being two collection periods during each phase of the feeding trial. Feed offered during the collection periods was held constant and any refused was dried, weighed and deducted from the amount offered.

Trial 2. This trial was designed to test the effects of a dried rumen product when sheep were fed a high-roughage ration of low quality at two levels of protein. The trial was conducted in a similar manner as in trial 1. Similar wethers were used but none had received dried rumen product previously.

The wethers were fed a low-protein ration for 28 days. This was followed by a 28-day period on a high-protein ration (table 1). The dried rumen product was added to the rations of the test lots to supply 0.5 gm. of the product per lb. of total ration. Two groups of four wethers were individually fed the basal low-protein ration and two groups of four were

fed the ration plus the dried rumen product. After this period on the low-protein rations, the protein content was increased to 12.0% by the addition of soybean meal (table 1). During the high-protein phase, one of the previous basal groups received the dried rumen product and one of the groups previously fed the dried rumen product received the basal ration.

It was expected that the sheep would lose weight on the low-protein ration and thus test the dried rumen product under stress conditions. The high-protein phase was included to determine if the dried rumen product had any additional value over increasing the protein content of the ration during the recovery phase.

TABLE 1. COMPOSITION OF BASAL RATIONS USED IN TRIAL 2

Ingredients	7.4% protein ration	12.0% protein ration
Prairie hay	66.7	66.7
Corn cobs	15.2	10.8
Car-Mo-Las [a]	10.1	7.2
Soybean oil meal	....	9.7
Bone meal	4.0	2.8
Trace-mineralized salt	4.0	2.8

[a] Car-Mo-Las is a commercial product composed of 65% molasses dried on a corn cob base.

Total fecal collections were made for 5 days during the second and fourth weeks of each of the 28-day feeding trials. Procedures were the same as in trial 1. One lamb refused to eat an adequate amount of feed and was not included in results (table 4).

Results and Discussion

In Vitro Cellulose Digestion. Results of the *in vitro* fermentations indicate that fresh rumen fluid was superior to dried rumen product as a source of rumen microorganisms (table 2). No additional cellulose digestion above that of fresh rumen fluid could be shown by addition of both rumen fluid and a dried rumen product to the fermentation media. Tucker *et al.* (1956) also found little or no cellulose digestion by dried rumen innoculum.

In order more closely to compare the activity of equivalent numbers of organisms from rumen fluid and from dried material, an amount of fluid equal to the amount of fluid used for fermentations was lypholized. The results indicate that drying under these conditions decreased cellulose digestion from 67.7% to less than 10.0% (table 2). It would appear that drying of rumen fluid must be done under more exacting conditions than vacuum and low temperature in order to produce a dry rumen product with any significant bacterial activity. The loss of activity upon drying was also indicated by higher breed cell count as compared to plate colony count. Feeding of the dried product over a two-month period did not increase plate colony count of fresh rumen innoculum taken from sheep via

TABLE 2. *IN VITRO* DIGESTION COMPARISON OF FRESH RUMEN FLUID, LYPHOLIZED FRESH RUMEN FLUID AND DRIED RUMEN PRODUCTS AS SOURCES OF RUMEN MICROORGANISMS

Bacterial source	Amount added per flask, ml. and gm.	Cellulose digested in 36 hours,[c] %
Fresh rumen fluid	40 ml.	80.1
D.R.P. "A"[a]	1 gm.	12.5
D.R.P. "B"[b]	1 gm.	Less than 10.0
D.R.P. "A" plus fresh rumen fluid	1 gm.+40 ml.	80.5
Fresh rumen fluid	40 ml.	67.6[d]
Fresh rumen fluid lypholized	40 ml. residue	Less than 10.0[d]
D.R.P. "A"	1 gm.	Less than 10.0[d]

[a] Dried rumen product concentrate B238 "Rufus" prepared from rumen contents.
[b] Dried rumen product "Rumenade" cultured organisms on carriers.
[c] Average of five determinations.
[d] Average of three determinations and 30 hours fermentation time.

rumen cannula. The average plate colony count of 30 samples taken from four sheep fed dried rumen product was 7.3×10^9 while the average count of rumen fluid from four sheep not receiving dried rumen product over the same period was 7.9×10^9.

Feeding and Digestion Trials. Rate of gain and feed efficiency were very similar for the supplemented and unsupplemented groups in trial 1. It appears the dried rumen product had no stimulating effect on rate of gain, feed efficiency or consumption of feed during either the high or low-concentrate phases. The average apparent digestion coefficients of the various nutrients show no significant differences ($P > 0.05$) between the basal group and the supplemented group (table 3). Ronning *et al.* (1957) and Tucker *et al.*

TABLE 3. SUMMARY OF WEIGHT GAINS, FEED EFFICIENCY AND APPARENT DIGESTION COEFFICIENTS DURING TRIAL I

	High-concentrate phase		Low-concentrate phase	
Items	Basal	D.R.P.[b]	Basal	D.R.P.
Number of animals	4	4	4	4
Days in period	56	56	32	32
Av. initial wt., lb.	87.5	86.5	106.7	105.5
Av. daily gain, lb.	0.38	0.38	0.23	0.23
Av. daily feed, lb.	2.74	2.77	4.02	3.88
Feed/100 lb. gain, lb.	731	730	1773	1711
Av. digestibility, %[a]				
Dry matter	63.36	64.13	66.72	65.72
Crude protein	72.89	75.05	77.33	76.54
Ether extract	61.02	55.29	47.03	47.79
Crude fiber	25.07	29.04	39.33	38.89
Nitrogen-free extract	74.25	74.40	78.52	77.03

[a] Each value represents an average of eight determinations.
[b] Dried rumen product used in all feeding trials was "Natural Rufus Concentrate".

(1956) reported no response from feeding dried rumen products to dairy cattle and sheep, respectively. Williams and Jensen, (1954) obtained no benefit from feeding dried rumen contents in a milk replacement ration to young calves.

During the first 4 weeks of trial 2 when the lambs were fed the low-protein, high-roughage rations, most of them lost weight. The averages for

TABLE 4. SUMMARY OF FEED EFFICIENCY, WEIGHT GAINS AND APPARENT DIGESTION COEFFICIENTS DURING TRIAL II

Group number	1	2	3	4
	Phase 1 (7.4% protein ration)			
Number of animals	4	4	4*	4*
Days in period	28	28	28	28
Av. initial wt., lb.	112.7	111.2	111.2	113.5
Av. daily gain, lb.	0.045	0.001	—.080	—.116
Av. daily feed, lb.	2.43	2.32	2.36	2.40
Av. digestibility [a]				
Dry matter	51.24		53.33	
Crude protein	41.41		46.54	
Ether extract	—2.68		18.86	
Crude fiber	62.72		63.51	
Nitrogen-free extract	50.97		51.23	
	Phase 2 (12.0% protein ration)			
Number of animals	4*	4	3*[b]	4
Days in period	28	28	28	28
Av. initial wt., lb.	114.0	111.5	109.0	110.5
Av. daily gain, lb.	0.107	0.170	0.190	0.196
Av. daily feed, lb.	3.14	2.86	2.99	3.07
Av. digestibility [c]				
Dry matter	56.57	58.14	57.78	58.87
Crude protein	66.84	69.15	67.88	69.93
Ether extract	23.00	32.84	30.07	31.98
Crude fiber	60.70	63.69	63.69	62.59
Nitrogen-free extract	55.91	56.48	55.75	58.33

* Denotes groups supplemented with dried rumen product.
[a] Average of eight lambs.
[b] Average of three lambs. One lamb refused to consume an adequate amount of the ration and was not included in the group results.
[c] Average of four lambs.

the lambs fed the basal ration showed slight weight gains while the averages for the groups fed the dried rumen product showed slight losses (table 4). The feed consumption of 2.3 to 2.4 lb. daily showed the rations to be palatable. There were only slight differences in feed consumption between the control and dried rumen product groups.

Increasing the protein content of the low-quality, high-roughage ration by the addition of soybean meal resulted in improved feed consumption and increased rates of gain. The rate of gain seemed to be more closely related to the gain during the previous period than to the presence or absence of

the dried rumen product. Feed consumption also was not affected by the product.

Digestion coefficients for various nutrients in the rations are presented in table 4. Digestibility of crude protein and ether extract was higher with the rations supplemented with the dried rumen product when the low-protein ration was fed. The differences in protein digestion by the lambs were not significant at the 5% level of probability, but the differences in ether extract digestion were significant at the 1% level. Six of the lambs in the control groups, but only three of eight fed the dried rumen product, had negative digestion coefficients for ether extract.

Supplementing the low protein rations with soybean meal improved digestibility of all nutrients except crude fiber. There were only small differences between the rations with and without the dried rumen product.

Summary

In vitro experiments and two feeding and digestion trials with sheep were conducted to test the activity and feeding value of dried rumen products. *In vitro* digestion comparisons with fresh rumen fluid showed no replacement value or additive benefits for dried rumen products. In feeding and digestion trials, wether lambs were fed high and low-concentrate rations and also low-quality roughage rations containing 7.4 and 12.0% total protein. It appeared that dried rumen products had no stimulatory effect on rate of gain, feed efficiency, feed consumption or digestibility of major nutrients with any of the rations.

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EXTENSION ANIMAL HUSBANDMAN'S AWARD

A. Name of Award: American Society of Animal Production Extension Award.

B. Donor: Chas. Pfizer and Co., Inc.

C. Description of Award: $1,000 and appropriate memento.

D. Purpose: Recognition of outstanding achievements in the field of Animal Husbandry Extension.

E. Administration of the Award: The American Society of Animal Production has sole right of selection of the recipient of the award and of the formulation of procedure governing such selection.

F. Eligibility for Nomination:

1. A nominee must have made an outstanding and noteworthy contribution in the field of Extension Animal Husbandry. The contribution must pertain to the following classes of animals: (a) beef cattle, (b) swine, or (c) sheep. Such a contribution may be in the initiation and development of programs and projects in the breeding, feeding, management, and health and sanitation, and/or to the meats of the animals listed above, or to 4-H Clubs and junior livestock programs, cooperative livestock associations, and to other activities directly related to meat animal production.
2. The nominee must be living and actively engaged as an extension specialist employed by a State (provincial) or Federal Extension Service and devoting at least 50 percent of his time to Extension meat animal programs at the time of nomination.
3. A nominee must be a member in good standing of the American Society of Animal Production.
4. There is no limit to the number of times a member can be nominated but an individual cannot receive the award more than one time.

G. Nomination for the Award:

1. Any member in good standing of the American Society of Animal Production may make a nomination, except if such member is an officer or member of the Executive Committee of the Society or a member of the Award Committee.
2. A member may nominate no more than one person in any one year for this award.

3. Nominations are to be sent to the secretary of the Society by June 15 of the fiscal year in which the award is to be made; nominations received subsequent to this date will not be eligible for consideration.

H. Award Selection Committee:

1. The Award Committee shall consist of the director of the American Society of Animal Production and four members appointed by the president of the Society with the advice and approval of the Executive Committee. The director shall serve as chairman. The four members shall be selected on the basis of one each from the Northeastern, North Central, Southern, and Western Regions.
2. Two members will be appointed each year and will serve a two-year term. No member shall serve on the committee for two consecutive terms. (Exception: the first year the award is put into effect there shall be appointed two members for two years and two members for one year.)
3. Not less than two members of the committee shall be actively engaged in full-time animal husbandry extension work.
4. Vacancies that occur in the committee shall be filled by appointees named by the president.
5. In the event that a committee member is nominated for the award he becomes disqualified for service on the committee during the period in which he is under nomination. The Society secretary shall notify the president of this fact and the president shall then request the member to step down and shall make an interim appointment to the committee for that award year.

I. Selection of Award Recipient:

1. All nominations must be accompanied by:
   (a) A brief biography of the nominee.
   (b) Extent of acceptance and application of his concepts, recommended techniques, programs, etc.
   (c) Influence of his projects, programs, and the like on the livestock industry and the welfare of farm people.
   (d) Qualities of leadership as demonstrated by ability to influence others to act and adopt improved practices.
2. After nominations have been made, solicitation on behalf of any nominee by individuals, groups, or institutions will not be tolerated and such solicitation will automatically disqualify such nominee.
3. All nominations, together with supporting material, received by the secretary will be transmitted to the chairman of the Award Committee immediately after closing date (June 15) for nomination and the committee shall report its selection to the secretary not later

than September 15. The material supporting nominations may be held by the Award Committee for such period of time as desired and then returned to the person who made the submission.

4. Any member of the Award Committee may ask the secretary to request additional information about a nominee from the principal nominator. Such additional information must be sent to the secretary who will transmit same to all members of the committee.
5. The decision of the Award Committee shall be final. If the committee decides none is worthy of the award, no award will be made that year.
6. A nomination made in one year may be considered in subsequent years by the Award Committee.

J. The presentation of the award will be made under appropriate circumstances at the time of the annual meeting of the American Society of Animal Production.

K. The Executive Committee may make necessary changes in these regulations for awards in subsequent years.

NOMINATION AND SELECTION OF HONORARY FELLOWS OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

1. The Executive Committee recommends that the Society establish the title of Honorary Fellow for persons who have rendered very distinguished service in the field of Animal Industry and/or to this Society over a period of at least 25 years and who are in good standing in the Society now or at the time of retirement.

2. One person per year may be selected from each of the five following categories: Teaching, research, extension, administration and industry. In addition, not to exceed three Honorary Fellows may be selected irrespective of category. Thus the total for any one year shall not exceed eight.

3. Persons designated as Honorary Fellows shall be presented an appropriate certificate or scroll at the annual meeting of the Society, and will be given a life membership in the Society.

4. The Executive Committee of the Society shall appoint a committee of five to select Honorary Fellows. The Committee on Honorary Fellows will be a standing committee. In order to provide some continuity to the Committee, it is recommended that three members of this Committee shall be replaced every year. Selection of representatives on the committee should recognize geographic distribution and area of interest.

5. Nominations for Honorary Fellow must be received in the secretary's office by June 15 from a member of the Society who is in good standing. In order that each member of the Committe may have a copy of the material submitted in behalf of a candidate, it is required that five copies be submitted to the secretary of the Society. This material should contain a biographical sketch of the nominee and a list of his accomplishments and contributions to the industry and/or to the Society.

6. The Committee may be guided by but not limited to the nominations so made. Members of the Executive Committee of the Society and members of the Fellow Award Committee will be ineligible for this Award while serving in such capacities.

7. On or before September 15, the Committee will submit its selections to the secretary of the Society.

8. All committe deliberations regarding Honorary Fellows shall be kept in confidence by the Committee.

9. It will be the responsibility of the Fellow Award Committee to take the means necessary by October 15 to encourage attendance at the annual meeting of the recipients of the award.

10. The award will be presented by the Chairman of the Award Committee.

NEWS AND NOTES

Meeting of the American Society of Animal Production. The 51st annual meeting will be held at the Hotel Sherman, Chicago, Friday and Saturday, November 27 and 28, 1959. Members will be sent a questionnaire in June regarding papers. Titles of papers are to be submitted to the secretary's office by July 20, and abstracts are to be submitted by August 15. Authors of papers must be members of the Society, but associate authors may be non-members.

The Western Section of the Society and the Western Division of the American Dairy Science Association will hold joint meetings on the campus of the University of Arizona, Tucson, July 13–15, 1959.

The North Atlantic Section of the Society will meet at the University of Connecticut, Storrs, August 25–26, 1959.

Nominations for the Morrison Award. The rules governing this award were amended in 1952 and are now as published in J. Animal Sci., Vol. 11, No. 4, pp. 807–809. All nominations are due in the secretary's office by June 15. Nominations must be accompanied by a brief biography of the nominee, a list and reprints of publications concerning the research, and a statement of the importance of this research to the livestock industry and animal science. The cash award will be $1,500 and a gold watch.

Nominations for the American Feed Manufacturers' Award. The rules governing this award are published in the J. Animal Sci., Vol. 7, No. 2, pp. 257–258, 1948. Two changes have been made in the rules to include (1) research work published during the three years immediately preceding the year of recognition (this has formerly been a two-year period) and (2) that the recipient must be affiliated with a public institution, hospital or similar organization at the time of selection. Nominations are due in the secretary's office by June 15. The research must be in the fields of beef cattle, horse, sheep and/or swine nutrition. The cash award is a check for $1,000 presented by the American Feed Manufacturers' Association.

Nominations for Extension Animal Husbandman's Award. A $1,000 award to be known as the American Society of Animal Production Extension Award will be made in 1959 to an outstanding specialist in the field of animal husbandry extension. Plans for the new award were completed at the closing session of the 50th Annual meeting of the Society in Chicago. Chas. Pfizer and Co., Inc. is the donor. The award will recognize the extension worker employed by a State, Provincial, or Federal Extension Service who shows superior abilities in serving the livestock industry of his state or country. The rules governing this award are published in this issue of the Journal, Vol. 18, No. 2, pp. 855–857. All nominations are due in the secretary's office by June 15. Nominations must be accompanied by a brief biography of the nominee, and a summary of his qualifications and achievements as outlined in the above mentioned rules.

Nominations for Fellows of the American Society of Animal Production. Rules governing nomination and selection of Fellows are given in this issue of the Journal, Vol. 18, No. 2, p. 858. All nominations are due in the secretary's office by June 15. Nominations must be accompanied by five copies of a biographical sketch of the nominee and a list of his accomplishments and contributions to animal industry and/or the Society.

A National Conference on Beef Research is being organized for October 19–20, 1959, under the sponsorship of the Agricultural Research Institute, Agricultural Board, NAS-NRC. The conference will be held at Purdue University. Dr. A. O. Rhoad, King

Ranch, Kingsville, Texas, is chairman of the organizing committee. The conference is being supported by industry, cattlemen's associations, and interested groups. The general theme for the conference is to focus attention on research needs (1) to establish the beef we want in terms of consumer requirements and preferences, (2) to describe beef in terms of grade and quality, (3) to produce it economically. Further information can be obtained from Dr. Rhoad, or you may want to check with the Agricultural Research Institute, 2101 Constitution Ave., Washington, D. C.

The British Society of Animal Production is sponsoring publication of a new scientific Journal which will cover research progress in the entire field of animal production in Great Britain, including genetics, husbandry, nutrition, physiology, and the interrelationships of animals and environs. Initially, two numbers will be published annually, in March and September, at the annual rate of $5.00. Subscriptions may be placed with Messrs. Oliver and Boyd, Ltd., Tweeddale Court, High Street, Edinburgh, Scotland.

Readers of the Journal may be interested to know about the quarterly publication *Animal Breeding Abstracts* prepared by the Commonwealth Bureau of Animal Breeding and Genetics in Scotland. *Animal Breeding Abstracts* provides a valuable service to research workers and others interested in the latest developments in the science of animal breeding. It is published quarterly and contains annually four major reviews and 2,300 abstracts and titles of papers published in the world's literature. It covers not only breeding and genetics, but reproduction, including A.I., growth and productivity in farm livestock, poultry and laboratory mammals. About 45 percent of the abstracts are made from foreign language publications and one-fifth are from American journals. The subscription rate for four issues and subject and author indexes is $9.10. Payment may be made by check direct to the Commonwealth Agricultural Bureaux, Central Sales, Farnham Royal, Bucks., England.

Genetic Resistance to Disease in Domestic Animals by F. B. Hutt; 198 pages; $3.50; Cornell University Press, Ithaca, N. Y., 1958. In the words of the author, this book is the outgrowth of a series of lectures given at North Carolina State College in 1956, it being his firm conviction that the biological fitness of domestic animals to cope with their environment, including disease, can be greatly increased by selective breeding. Evidence of variation among animals in genetic susceptibility to disease is reviewed and illustrated in a convincing manner under such chapter headings as Innate Disease, Coping with the Environment, Resistant Big Animals, (swine, sheep, goats, cattle, the horse) Resistant Birds, Aberrant Metabolism and others. Ways to use resistance which are implied throughout the book form the subject of the final chapter. Investigators in all branches of animal science will be interested in this carefully documented account of research bearing upon an important phase of livestock health and production.

Joseph D. Shroder, associate in the Department of Animal Husbandry, Iowa State College, has accepted a position as Animal Nutritionist with Hales and Hunter Co., Chicago, Illinois.

Ralph M. Durham has resigned his extension position in Animal Husbandry at Iowa State College to become Head of the Animal Husbandry Department, Texas Technological College, Lubbock, Texas. He takes over his new duties on May 1.

Robert E. Rust joined the Animal Husbandry Department of Iowa State College in February of this year. He will develop an extension program in meats and assist in consumer research studies. Mr. Rust was formerly engaged in similar work at Michigan State University.

Mason H. Campbell, Dean of the College of Agriculture and Director of the Rhode Island Agricultural Experiment Station since 1942, will retire on June 30, 1959. From 1918 to 1927 Dean Campbell was an instructor and associate in Dairy Husbandry

at the University of Illinois, and from 1927 to 1941 Professor of Dairy Production at the University of Vermont. In 1941–42 he was production manager of the Walker-Gordon Laboratories of New England. Dean Campbell was on leave from the University of Rhode Island between February 1, 1954 and August 31, 1955 to serve as chief agriculturist on a United States Operations Mission in Egypt.

Gustav Bohstedt, Visiting Professor of Animal Industries at Southern Illinois University since September, 1957, has retired for the second time. He first retired in 1957 as Head of the Animal Husbandry Department at the University of Wisconsin where he had been on the faculty for nearly 35 years. At SIU, Dr. Bohstedt taught animal husbandry courses and advised the School of Agriculture on developing graduate work in its Department of Animal Industries.

Louis L. Rusoff, Dairy Nutritionist and Professor of Dairying at Louisiana State University, was presented the Charles E. Coates Memorial Award at a dinner attended by members of the Baton Rouge chapters of the American Chemical Society and the American Institute of Chemical Engineers, who sponsor the annual award. The presentation was made by President Troy H. Middleton of LSU. The award is presented to a leading chemist or chemical engineer in the Baton Rouge area. Dr. Rusoff was selected for his pioneering work in nutritional antibiotic research and other studies in biological and nutritional chemistry which have led to the publication of more than 100 scientific papers.

Lewis Holland has been appointed Associate Professor of Animal Husbandry at New Mexico State University. Dr. Holland succeeds Dr. Robert L. Blackwell, who became Director of the U. S. Sheep Experiment Station and Western Sheep Breeding Laboratory, Dubois, Idaho, on January 5. Dr. Holland has been Assistant Professor of Animal Husbandry at Kansas State College since 1951. He was reared in the Hatch Valley and graduated from New Mexico State University in 1949, was awarded his M.S. degree at Colorado State University in 1951, and his Ph.D. at Iowa State in 1957.

N. P. Ralston, former Head of Michigan State University's Dairy Husbandry Department, has been named Director of Extension and Assistant Dean of the College of Agriculture. Dr. Ralston received his B.S. and M.A. degrees from the University of Missouri and his Ph.D. from Cornell.

James A. Christian has been appointed Animal Husbandman on the Georgia Agricultural Extension Service staff and will be stationed at Athens. He comes from Macon where he was manager and partner in a farming enterprise. Mr. Christian received his B.S. and M.S. degrees in Animal Husbandry from Pennsylvania State University.

William A. Ljungdahl has joined the New Mexico State University's Agricultural Extension staff as Animal Husbandman. He has had extensive experience in livestock production in New Jersey, Texas and Kansas. Mr. Ljungdahl is an Animal Husbandry graduate of Kansas State College and also holds an M.S. degree in Animal Husbandry from Michigan State College.

Max K. Hinds, since 1951 on the Federal Extension Service Division of Agricultural Economics staff, has moved over to the Agricultural Research Service staff as Executive Secretary of the Livestock, Dairy, Poultry, and Sheep and Wool RMA Advisory Committees. He succeeds Henry W. Marston.

Jack L. Ruttle, Animal Husbandman at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, resigned January 10, 1959, to accept the position of Extension Animal Husbandman in the sheep and wool work at New Mexico State University.

Charles E. Summers was appointed Extension Animal Husbandman at Iowa State, March 1, 1959. He is a native of Kentucky, received his B.S. and M.S. from the University of Kentucky and his Ph.D. from Iowa State.

Henry G. Zavoral, Extension Animal Husbandman, retired February 15, 1959, after 37 years of outstanding service with the University of Minnesota. He pioneered in promotion of barrow shows and meat-type hog production and for the past 12 years has served as moderator for the National Barrow Show at Austin, Minnesota.

John R. Stauder changed from Extension Sheep and Wool Growers Specialist to Extension Sheep Specialist on January 11. He has been on the New Mexico Extension staff since 1954.

Duane Acker, Associate Professor of Animal Husbandry at Iowa State College, has been named Professor of the Year by the students in the Division of Agriculture for outstanding instruction in the classroom. Dr. Acker teaches freshman animal science and junior level courses in animal nutrition.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts." *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest to members. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. W. D. Gallup, Department of Biochemistry, Oklahoma State University, Stillwater, Oklahoma, or to the publishers: Boyd Printing Company, Inc., 49 Sheridan Ave., Albany 10, N. Y.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. H. H. Stonaker, Department of Animal Husbandry, Colorado State University, Fort Collins, Colo., or to the publishers, Boyd Printing Company, Inc., 49 Sheridan Ave., Albany 10, N. Y.